Mesozoic Geology of the Puerto Ingeniero Ibáñez area, 46° South, Chilean Patagonia

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Abstract

The Eastern Aysén Region of Patagonian Chile from 45°-47°S is characterised by Jurassic and Cretaceous silicic volcanic and volcaniclastic terrestrial rocks which outcrop on the eastern slopes of the Andes. In the Puerto Ibáñez area, 46°10'S 72°00'W, the Jurassic rocks have been mapped at 1:50,000 scale to determine new information on their stratigraphic relationships.

The Late Jurassic Ibáñez Formation rests on strongly deformed pelitic schists of probable Palaeozoic age, and reaches a maximum thickness in excess of 1000m within the area studied. Calc-alkaline silicic tuffs and ignimbrites dominate the Ibáñez Formation. Extrusive lavas are less common, but areas of dacitic to rhyolitic lavas and domes occur, as do minor andesitic lavas and pyroclastic rocks. Ignimbrites in this area are generally 5-20m thick, although some units show ponding in excess of 100m. Most are massive units, with simple cooling features, and columnar jointing is rare. Intercalated with the tuffs and ignimbrites are fluvial deposits, mass flow deposits and laminated pelites, as well as breccias, lithic tuffs and other volcaniclastic units. Ibáñez Formation rocks are moderately deformed by normal, oblique and reverse block faulting, although folding is rare. Locally below the upper contact with the marine sediments of the Lower Cretaceous Coyhaique Group, Ibáñez Formation rocks are weathered to a distinctive purple clay and deeply eroded. Infilling this apparent palaeotopography are later Ibáñez Formation andesitic lavas, some pyroclastics and a rhyolitic dome, with all in turn overlain by the Lower Cretaceous Coyhaique Group and/or the Divisadero Formation.

The Coyhaique Group in the Ibáñez area consists of the Katterfeld Formation of blackshales and the Apeleg Formation of tidal shelf, beach and deltaic sandstones, although outcrop is patchy and both formations are absent in some areas. Both formations of the Coyhaique Group are shown to rest unconformably on the Ibáñez Formation, and show gradational internal contacts with each other and with the overlying Divisadero Formation.

The Divisadero Formation is dominantly a floodplain volcaniclastic sandstone unit with basal deltaic and redbed sequences, followed by a main body of thick tuffaceous sandstones with intercalated calc-alkaline rhyolitic tuffs and ignimbrites. Measured sections from the Puerto Ibáñez Quadrangle, Cerro Montreal and Cerro Divisadero are presented to demonstrate the distal nature of the Puerto Ibáñez outcrops of Divisadero Formation units when compared with those exposed in the Coyhaique region.

Stratigraphically above the Divisadero Formation are coeval Plateau Basalts and the peralkaline rhyolite lavas of the Cerro Pico Rojo dome complex, both of which are of uncertain age and may date from the late Cretaceous to Tertiary, although a Miocene age is most likely.

The Mesozoic calc-alkaline silicic volcanic units and the Coyhaique group are intruded by calc-alkaline granodiorites and a mixed population of minor hypabyssal intrusions of dominantly calc alkaline affinity, although alkaline and peralkaline rocks also occur.

Geochemical data for all mapped igneous formations are presented, and radiometric Ar-Ar analyses for representative samples of the Ibáñez Formation, Divisadero Formation and the granodioritic intrusive rocks are presented.

The Ibáñez Formation, although still included as part of the huge silicic Chon Aike Province erupted in the Middle Jurassic, is confirmed to be significantly younger than the main Chon Aike Province and to have a closer affinity to volcanic arc activity on the Pacific rim of Gondwana than to earlier within-plate silicic magmatism of the continental interior. The granodiorites are shown to be of mid Cretaceous Albian-Turonian age, while dating of the Divisadero Formation at Cerro Divisadero proved to be inconclusive.

For Jenny

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Chapter 1

Introduction

Fieldwork for this thesis was carried out over three field seasons from December 1995 to January 1998, with 13 months of fieldwork completed in total. The initial mapping area was the Puerto Ibáñez Quadrangle, 46° south, Chilean Patagonia, which was mapped in cooperation with SERNAGEOMIN in the summer of 1995-96 (See Fig. 1.1). This area was then expanded for the summer of 1996-7 to include the southern part of the adjacent Cerro Farellón Quadrangle, as well as measured type sections from the Coyhaique exposures of the Divisadero Formation and of the base of the Ibáñez formation from Puerto Tranquilo and Cochrane. Final mapping of the eastern section of the Cerro Farellón area was completed in January 1998. Field support was supplied by SERNAGEOMIN and Fondecyt. The University of Canterbury Department of Geological Sciences and the Mason Trust supplied funding for airfares, additional field expenses and chemical analysis.

1.1 Location

The main field area is located at 46°, 15' S, 72°, 00' W (Fig. 1.1), and covers the whole of the Puerto Ingenierio Ibáñez 1:50,000 topographic sheet and the southern portion of the Cerro Farellón 1:50,000 sheet. For regional correlation, additional stratigraphic columns from the Aysén region were constructed at Cerro Divisadero, Cerro Montreal, Lago Frio and Lago Castor to investigate the type sections of the Divisadero Formation. A stratigraphic column was constructed at Lago Norte to illustrate important upper contacts of the Ibáñez Formation. Basement schists and marble were sampled at Puerto Tranquilo, Cochrane and the new road being constructed west of Puerto Tranquilo to Bahia Exploradores (Fig. 1.2).

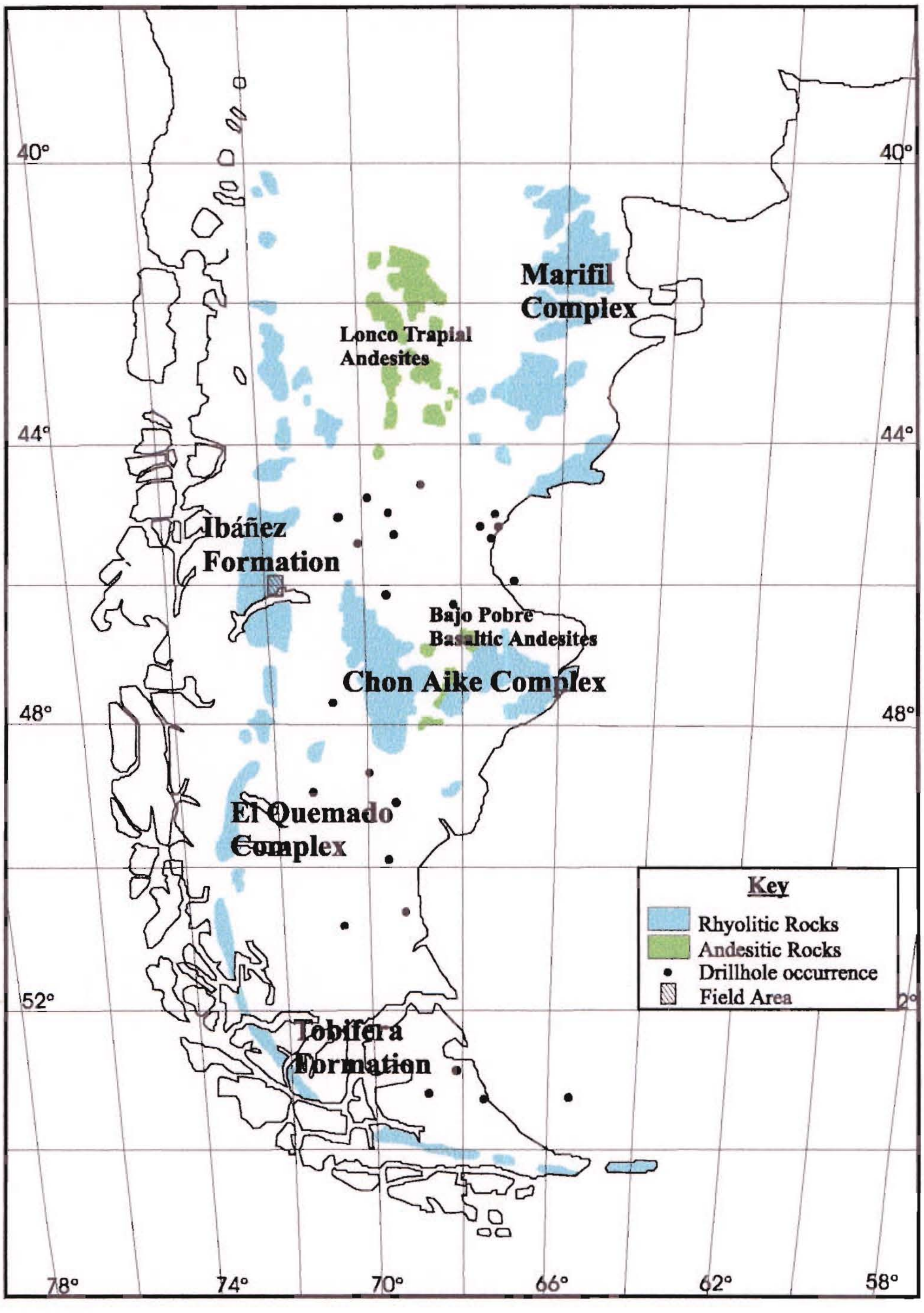

Figure 1.1: Location Map showing field area and distribution of silicic (blue) and andesitic (green) volcanic formations of Patagonia. Sub-surface occurrences in drill-holes marked with black dots. After Pankhurst and Rapela (1995) and Pankhurst et al. (2000).

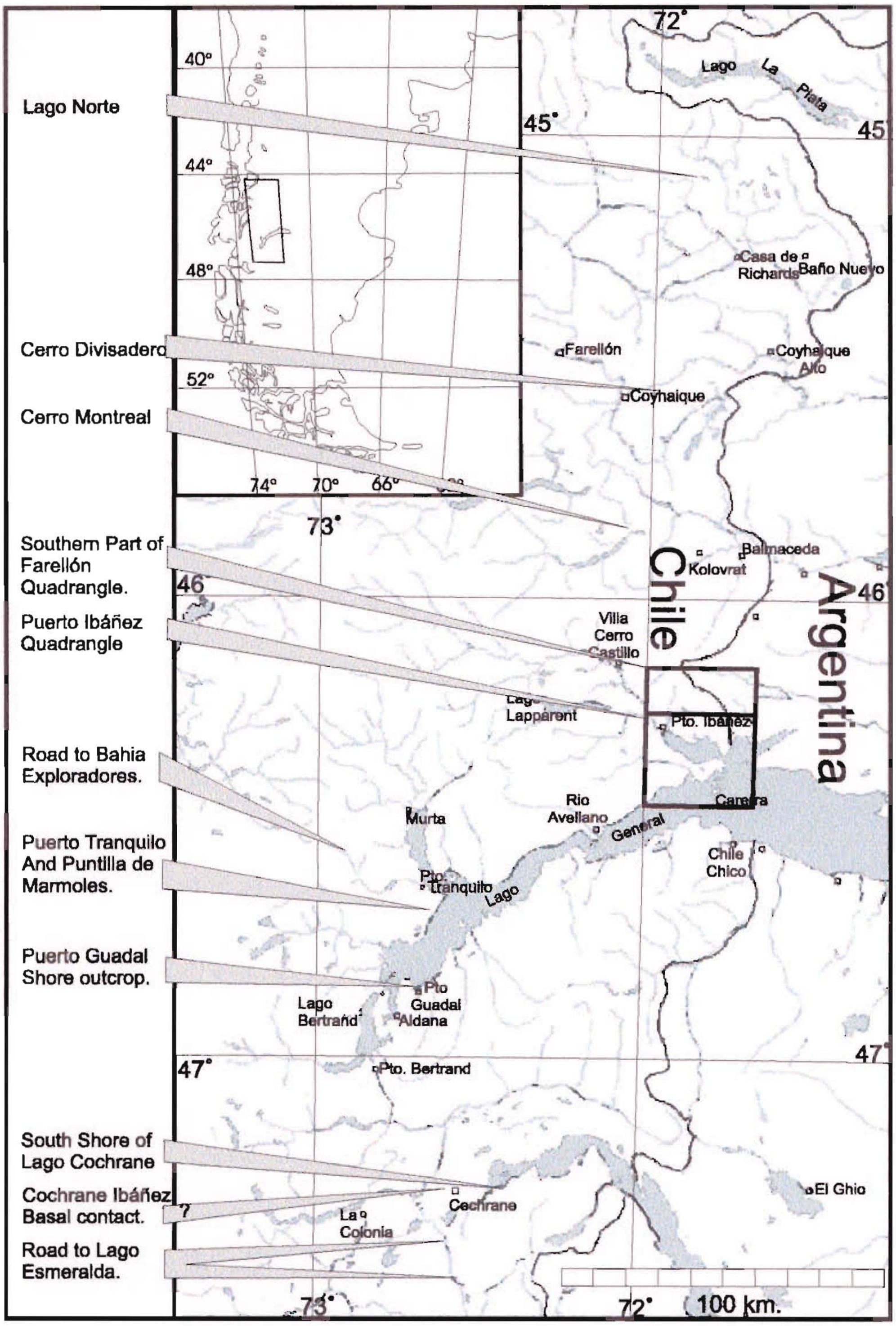

Figure 1.2: Location map showing field locations visited and main mapping Quadrangles.

1.2 Topography

The main mapping area encompasses a wide array of landforms on the eastern ranges of the Patagonian Andes. These vary from dry acacia scrub and tussock grasslands to high alpine meadows and glaciated peaks, with many minor variations.

In general, the southern part of the Puerto Ibáñez area is dominated by glaciated lowlands, with acacia scrub and spinifex grasses. Those areas covered with glacial moraine or alluvial gravels give rise to the best tussock grasslands and grazing. Fertile soils are sparse, and generally concentrated around active fluvial deltas, such as that at Puerto Ibáñez, and also at Peninsula Levicán. Around the lakeshore of Lago General Carrera are seen the remnants of five or six successive beach and delta terraces from high-stand periods due to ice dams present during and at the close of the last glaciation. The Rio Ibáñez valley itself is a wide glacial 'U-shape' valley, with steep sides modified by alluvial fans, and a floor composed of complex and irregular clumps of roche moutonées that are controlled by local northwest-southeast, north-south and southwest-northeast normal and oblique faulting and jointing (Fig. 1.3). It is notable that on the satellite photo of the area, the Rio Ibáñez valley follows a lineament that extends some 40-50km from the Puerto Ibáñez area northwest towards Cerro Castillo and beyond (Fig. 1.4). This lineament is also reflected in the structural geology and faulting of the northwest of the Ibáñez Quadrangle (Fig. 1.3). The general trend of the lineament also parallels the edge of a gravity low beneath the Ibáñez area, which is interpreted as a slab-window in the subducting slab derived from the area of ridge collision offshore of the Taitao Peninsula (Murdie et al., 2000).

The driest areas are the lowlands of the Peninsula Levicán and the Peninsula Ibáñez, both of which are glacially smoothed, low-lying sheets of rocks. These areas are typical of the 'steppe' landscapes encountered throughout extra-Andean Patagonia, and are vegetated with calafate (*Berberis microphilla*) and other scrub species, (*Berberis, Festuca and Chiliotrichium spp*), spinifex grasses and tussock (Skarmeta, 1978), with areas of surface evaporite deposition around small brackish and saline ephemeral lakes within depressions.

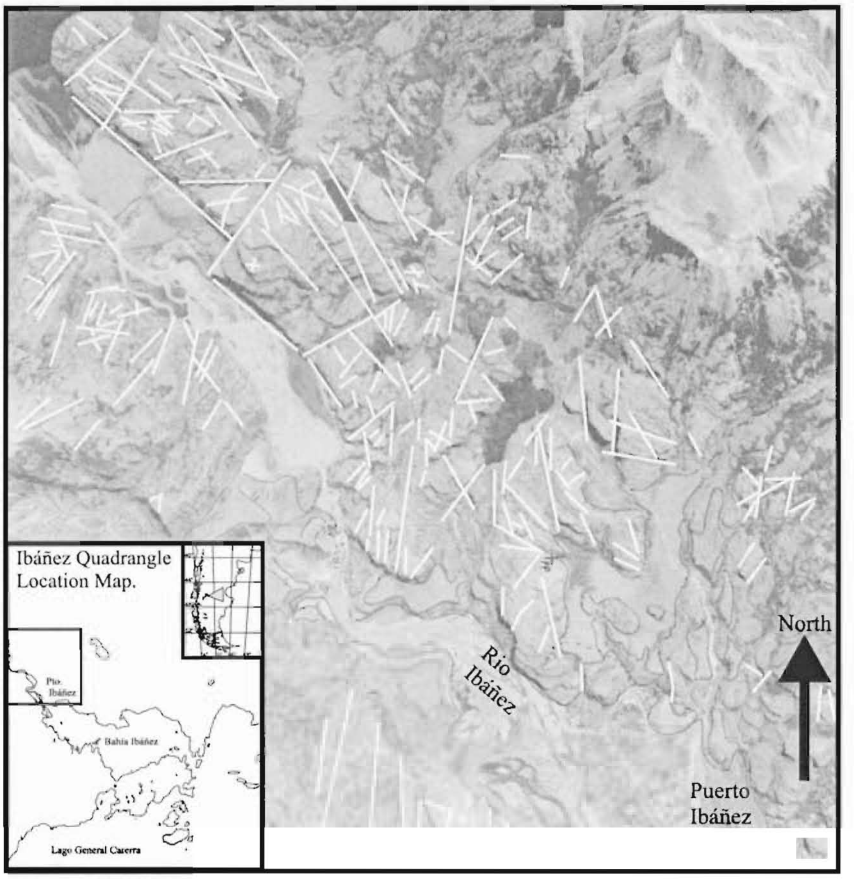

Figure 1.3: Roche moutonée fields controlled by jointing and faulting (normal and oblique) of the Ibáñez Formation in the Rio Ibáñez valley. White lines indicate trends of faults and joints. Note transition from SE-NW/SW-NE structure the top right to mainly N-S oriented faults and joints nearer Puerto Ibáñez in the bottom center of the view.

The shores of both peninsulas have several sets of remnant beach terraces from previous high-stands of Lago General Carrera.

The mid-range hills from approximately 500m up to about 1100m, are steeply sloping glacial valley sides, deeply incised with postglacial stream erosion and masked by active alluvial fans. These slopes are actively eroding after the destruction of their forest cover in the past 80 years, although pockets of Nothofagus beech forest still survive at higher altitudes or in deeper valleys unaffected by the anthropogenic fires of the 1920s and '30s. Much of the land cleared by fire is still covered with thousands of charred tree trunks, used by the local farmers as firewood and for post and rail fences. The cleared land not grazed has been colonised by alpine scrub and pockets of regenerating Nothofagus

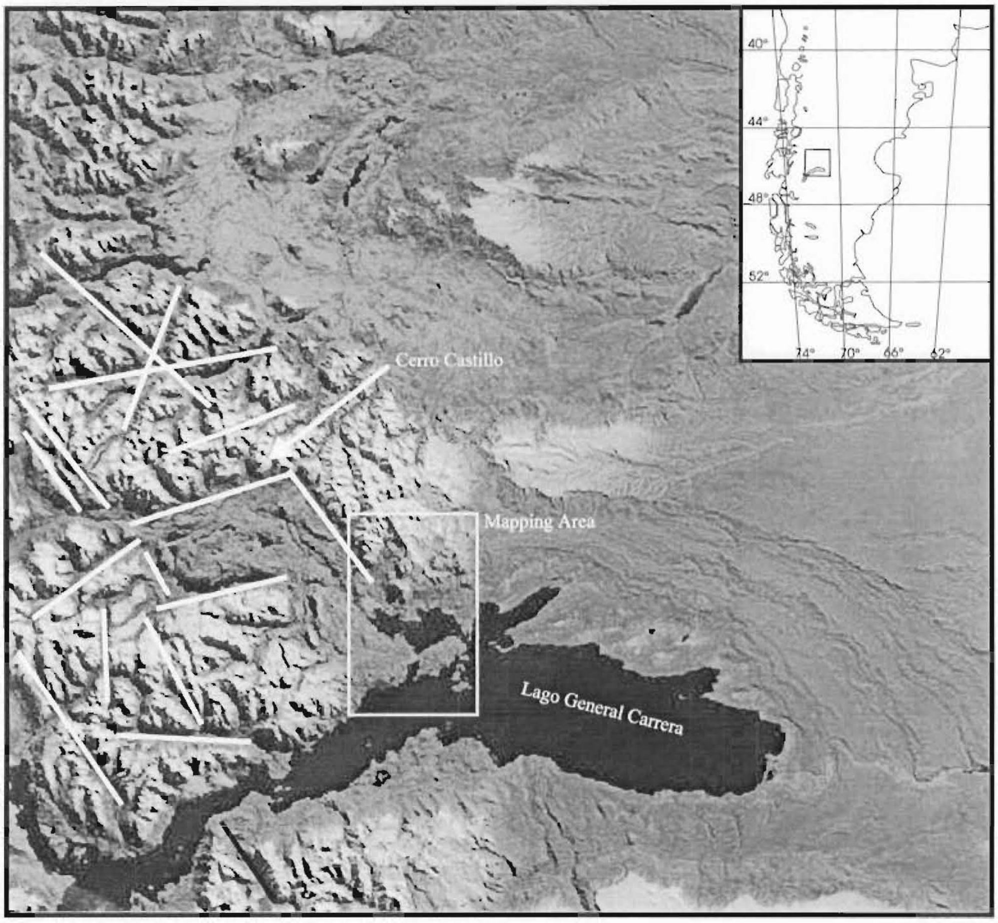

Figure 1.4: Landsat 7 enhanced thematic mapper image of Lago General Carrera and environs, showing in white structural lineaments, particularly the northwest trend of the Rio Ibáñez valley towards Cerro Castillo, and the moraine arcs to the east of Lago General Carrera/Buenos Aires (USGS, 1999).

forest, of these species: evergreen coigue (*Nothofagus betuloides*) and ñire (*Nothofagus antarctica*) and the deciduous leña (*Nothofagus pumilio*)(Skarmeta, 1978). Coigue forest dominates plateau areas which are still forested, whereas leña and ñire forest are more common as regrowth in cleared areas and remnants in lower altitude sheltered valleys. In the north of the area mapped, around Arroyo Rocoso, the leña forests are being logged for local timber and firewood.

High alpine areas of Cerro Farellón, Cerro Pirámide and Cerro Pico Rojo have fairly large areas on the plateaux between peaks which have beech forest remnants on their lower slopes, up to about 1200m, above which are alpine meadows and swamps. Between Cerro Pirámide and Cerro Pico Rojo the plateau is covered with poorly vegetated glacial moraine, including terminal moraines, Kame terraces, kettle lakes, etc., with alternating alpine meadows and Nothofagus forest. The stepped landslide and plateau area below Cerro Manchón, which ranges from 800-1300m, has at its lower edge dense Nothofagus forest, which gives way to swampy alpine meadows and glacial outwash terraces at its upper and northern parts. This area is also much deformed by active landslides and slumping in the weak, water-saturated parts of the Katterfeld Formation.

High peaks reach up to 2000m, with some icefields and cirque glaciers (Fig. 1.5). Whereas Cerro Pirámide proper and its northern peak have forms dominated by their geology and the shape of the underlying intrusive rocks, the relatively flat-lying tuffs that make up the upper parts of Cerro Farellón have allowed several small cirque glaciers to coalesce against an irregular central ridge line, producing a southwest to northeast oriented ridge with several peaks, surrounded by outward facing cirques. This irregular massif has extensive outwash terraces on its flanks, as well as active screes surrounding the steeper slopes without permanent ice cover. Only the three northeastern cirque glaciers on Cerro Farellón are still active, and these appear to be in retreat. The other cirques contain semi-permanent snowfields and areas of stagnant glacial ice beneath moraine cover. The intrusive microgranitoid bodies which surround the central massif of Cerro Farellón appear to have had little controlling effect on the shape of the mountain.

Typical fauna encountered in the region, other than the domesticated sheep, cattle and horses of local farmers, include guanaco, rare puma, rock eagles, and many condor in the higher mountain plateaux and forests. The Nothofagus forests of the foothills occasionally have remnant populations of endangered huemule (Patagonian forest deer) and a wide range of bird life including parakeets, woodpeckers and hawks. River flats around the Rio Ibáñez and Lago General Carrera are frequented by black swan, ibis, spurwing plover and spoonbill species, while occasional flamingo were encountered on the small saline playa lakes of the Peninsula Levicán. Steppe areas are almost devoid of animal fauna except for occasional eagles and condor, plus the ubiquitous armadillo.

Figure 1.5: Cerro Farellón cirque glaciers viewed from the south at GR 280040 4875980 1720m.

1.3 Previous Work and Geological Setting.

1.3.1 Previous Work

This summary of early geological mapping in the Puerto Ingenierio Ibáñez area follows that given in Skarmeta (1978). Mapping was begun by Caldenius (1932), who mapped the glacial geomorphology of the Lago General Carrera area at 1:500,000 scale, and correlated the later glaciation of the region with the Würm Glaciation of Europe. This was followed by the work of Heim (1940), who described the basement rocks to the west of the lake, and the rhyolites and tuffs of the Puerto Ibáñez area, and referred to them as the 'Ibáñez Series .' Ruiz (1945) carried out more detailed microscopic analysis of the metamorphic basement on the north side of the lake, and according to Skarmeta (1978), referred to '1500m of lavas, breccias, tuffs, and quartz porphyries', all of which were assigned to a 'Porphyry Series.'

During the 1960's, Ferreti (1961) reviewed the previous works and added new field mapping and photo-geological data to produce a 1:100,000 scale map of both the north and south shores of Lago General Carrera. Ferreti also suggested a single magmatic and mineralisation episode for the 'Diorita Andean.' Bowes et al. (1962) visited the regions around Puertos Ibáñez, Murta and Sanchez, during stream sampling for uranium, and produced a sketch map of the local geology. Also in that year, Katz (1962) presented a report for the Empresa Nacional de Petroleo, which recognised several 'complexes' in the north shore of Lago General Carrera, listed by Skarmeta (1978) as:

- Igneous rocks (undifferentiated and not dated)
- Divisadero Formation (assigned to the Upper Cretaceous)
- Extrusive Acid rocks (interpreted as probably Jurassic)
- Marbles and Phyllites (tentatively referred to the upper Paleozoic)

Similar to this system was the 1:250,000 scale map of the Aysén region produced by Lahsen (1967), which for the north shore of Lago General Carrera, listed the following units: Metamorphic Complex (Upper Paleozoic?), Caimito Formation (Upper Jurassic), Divisadero Formation (Upper Cretaceous) and finally Quaternary Volcanics.

Further work was carried out in the 1970s, with reconnaissance mapping along the edges of Lago General Carrera and stream sediment sampling (Espinosa and Stambuk, 1971). Reconnaissance mapping at 1:250,000 scale was carried out by Niemeyer (1975), who mapped the region between Lago General Carrera and the Rio Chacabuco, and Skarmeta (1974, 1976a, 1978), which covered the entire Aysén region east of the North Patagonian Batholith from 45°–46°. These mapping projects were based on extensive photo-geological study and fieldwork, and were instrumental in defining much of the stratigraphic nomenclature now in use in the region. Within the area of this study, these regional maps defined the approximate extent of the Ibáñez Formation, but overestimated the extent of the Coyhaique Group (then referred to as the Coyhaique Formation) and underestimated the outcrop extent of both the Divisadero Formation and Intrusive rocks related to the South Patagonian Batholith. They do include, however, the plateau basalts which overlie the Divisadero Formation. While the large scale of these maps and short field time precluded adequate coverage of fine detail, these maps established the stratigraphy of the Ibáñez Formation, Coyhaique Group and Divisadero Formation at 1:250,000 and 1:500,000 scale (Fig. 1.6).

The 1:500,000 scale map of the Peninsula de Taitao and Puerto Aysén produced by Niemeyer follows the stratigraphy mapped in the Ibáñez region by Skarmeta and Niemeyer, but later work (Bell et al., 1994; Suárez and de la Cruz, 1993) began to differentiate the member formations of those rocks that earlier workers had grouped into the Coyhaique Formation. This formation was upgraded to the Coyhaique Group and now consists of the Toqui Formation, the Katterfeld Formation (Ramos, 1981) and the Apeleg Formation (Ramos, 1981). Some recent workers have also begun to refer to the Ibáñez Formation as the 'Ibáñez Group' (Suárez and de la Cruz, 1997b), however, this nomenclature is premature. At this time, it is my opinion that the Ibáñez Formation at its present state of mapping detail has not had sufficient internal stratigraphic members or formations defined to allow its upgrading to a Group after the nomenclature of Salvador (1994). In the present study, the name Ibáñez Formation after Skarmeta (1978) and Niemeyer et al. (1984), will be followed. It must also be noted that the Ibáñez Formation can be regarded as synonymous with, or part of, the El Quemado Complex of Feruglio (1938) which has prior claim by earliest use in the literature. Rocks of the El Quemado Complex are very similar in age to the Ibáñez Formation, and it comprises a lithologically and geochemically similar group of basaltic andesite, andesite, dacite and rhyolitic rocks extending further to the south and east of the Ibáñez Formation within Argentina. The El Quemado Complex has been referred to as the El Quemado Formation by some authors (Pankhurst et al., 1998).

Previous to this study, the most recent work in the immediate mapping area (see Fig. 1.1) was brief reconnaissance mapping carried out in 1994–5, as part of the ongoing Aysén mapping project funded by SERNAGEOMIN and the local regional government.

1.3.2 Geological Setting

Middle and Upper Jurassic silicic volcanic rocks, locally named the Ibáñez Formation (Niemeyer, 1975; Skarmeta, 1978) overlie Palaeozoic semi-pelitic schists. Within the area mapped in summer 1995–96, the Palaeozoic schist basement does not occur as outcrops, but is common as lithic fragments in some of the ignimbrites, and as large xenoliths in one of the minor intrusive bodies. The Ibáñez Formation is at least 1000m thick, and consists of a faulted sequence of rhyolitic and dacitic domes, tuffs and ignimbrites, with some andesitic lavas and pyroclastic rocks, intercalated with continental lacustrine and fluvial sediments and minor marine incursions in the upper part of the unit (Covacevich et al., 1994).

The Ibáñez Formation has been variously ascribed to subduction-related volcanism (Demant, 1995; Gust et al., 1985) or grouped with the large Chon-Aike/Marifil/Tobifera silicic provinces (see also Fig. 1.1) and considered to be a result of large-scale crustal anatexis with fractionation of silicic rocks from andesitic parent magmas during the rifting precursor phase of Gondwana separation (Bruhn et al., 1978; Pankhurst and Rapela, 1995). More recent work on the petrogenesis of the Jurassic silicic volcanic event of Patagonia (Riley et al., 1998, 2001; Pankhurst et al., 1998, 2000) has given rise to a division of three distinct volcanic silicic events in Patagonia and the Antarctic Peninsula, with differing petrogeneses. Pankhurst et al. (2000) divide these events into V1 (188–178Ma), V2 (172–162Ma) and V3 (157–153Ma). The first event, V1, is represented in Patagonia by the Marifil Province, and the Mt Poster and Brennecke Formations of the Antarctic Peninsula; the second event, V2, by the Chon Aike Formation of the Deseado Massif and by the Mapple Formation of the Antarctic Peninsula; the final V3 event comprises the El Quemado Complex and Ibáñez Formations of Argentina and the east Chilean Andes, as well as parts of the western Chon Aike Formation and the basaltic andesites of the Bajo Pobre Formation (see also Fig. 1.1). The Tobifera Formation is considered to be diachronous, fitting in between the upper limit of the V1 event and the main V2 event (Pankhurst et al., 2000). The earlier V1 silicic volcanism is noted to be coincident temporally and spatially to the Ferrar and Karoo mafic magmatism associated with a plume event preceding Gondwana continental breakup, and V1 magmatism is related to a petrogenesis involving anatexis of lower crustal rocks by plume associated-mafic magmas, followed by fractionation and assimilation of crustal material in high-level magma chambers and eruption of voluminous silicic ignimbrites with a high Nb, high Zr 'within-plate' chemical signature (Pankhurst et al., 1998; Riley et al., 1998, 2001; Pankhurst et al., 2000). The V2 and V3 rocks, although still suggested to be derived from crustal anatexis, are associated with a westward younging of magmatism towards the active Andean margin, and hence a lessening of 'within-plate' geochemical characteristics and an increase in a destructive continental margin subduction related Nb depletion signatures. The Ibáñez Formation may be interpreted as part of the youngest V3 event, and although published geochemical data are sparse, the six samples of Baker et al. (1981), together with analyses presented in this study, show a typical Nb-poor subduction signature and support its inclusion in the V3 event of Pankhurst et al. (2000). Additionally, Parada et al. (2001) note the development of Ibáñez Formation as part of the earliest of three back-arc extensional volcanic events in the Aysén region, and suggest significant crustal contribution in the magma sources of the more southern examples.

Unconformably overlying the Jurassic igneous rocks is a transgressive-regressive sequence, the Lower Cretaceous Coyhaique Group, of shallow marine rocks forming the northern expression of the Austral Basin (Riccardi, 1988), termed the Aysén Basin after the local geographic region (Fig. 1.7 and Fig.1.8). This group consists of discontinuous limestones, tuffs and fossiliferous sandstones (Toqui Formation), overlain conformably by a thick (up to 600m) extensive unit of fossiliferous black shales (Katterfeld Formation), which in turn grades abruptly into the Apeleg Formation, a homogenous unit of ripple and trough cross bedded sub-tidal (and locally deltaic) shallow marine sandstones (Bell et al., 1994; Suárez and de la Cruz, 1993)(Fig 1.9). The Aysén Basin has been described as an ensialic back-arc basin occurring east of the Patagonian batholith (Townsend, 1995; Bell et al., 1994).

Overlying the Coyhaique Group are the volcaniclastic rocks of the Divisadero Formation, a Lower Cretaceous silicic volcanic unit with flood-plain and some deltaic deposits, together with widespread tuffs, ignimbrites and remnant rhyolitic, dacitic and andesitic eruptive centres (Niemeyer et al., 1984). Erupted through and overlying the Divisadero Formation are peralkaline rhyolitic domes (Cerro Pico Rojo), themselves overlain by patches of Late Cretaceous or Tertiary flood basalts, with remnant pyroclastic cones representing eruptive centres.

The entire sequence is cut by several generations of intrusives, the largest of which are the Middle Cretaceous high-level granitoids at Cerro Pirámide and Cerro Farellón, both of which may be reguarded as outliers of the main Patagonian Batholith to the west. There are also numerous local hypabyssal intrusives and dikes ranging from the Jurassic through to Tertiary and Recent. Active volcanism in the region is represented by Volcan Hudson, some 100km northwest, and there is also evidence of basaltic pyroclastic rocks and subglacial pillow lavas erupted during the last glaciation (Demant et al., 1998), which outcrop north of Villa Cerro Castillo on the road to Murta.

1.4 Aim and Scope of the Thesis

The aim of this programme is to produce a 1:50,000 scale lithostratigraphic geological map of the Mesozoic geology of the Ibáñez area and compare it with the surrounding regions. The map and thesis will be supported by geochemistry, petrology and Ar-Ar radiometric dating. The thesis will describe the Mesozoic stratigraphy and compare it with nearby outcrops of the same units and formations in the Aysén Region, and interpret the geology described in terms of the regional tectonics. These results will be added to the knowledge of the Mesozoic evolution of the Patagonian section of the Gondwana Margin.

1.5 Methods

Here follows a brief summary of methods used for field mapping, heavy mineral separation, thin sectioning, geochemistry laboratory techniques and subsequent data analysis.

Field mapping was carried out on foot or horseback, with a small team consisting of myself with one or two field assistants. Access to the areas being mapped was by four-wheel drive vehicle or hired local taxis where roads were of suitable condition (Four taxis were tested to destruction during the course of this thesis!). Mapping was mainly carried out through ridge and stream traverses across the field area to determine the main features and contacts, after which all contacts were either walked out or plotted from air photographs. All strike and dip measurements are according to the Right Hand Rule. Field geology and sample locations were plotted in the field on enlarged photocopies of air photographs purchased from the Instituto de Geographico Militare de Chile. During the evenings, these data were transferred from the photocopies to mylar overlays on other photocopies and on the actual air photos, and also plotted on the 1:50,000 topographic maps with the aid of stereoscopic viewing of the air photos and judicious use of GPS positions from Sony/Apple Newton Map-pad and Magellan handheld GPS systems.

Grid references stated in the text are UTM twelve-figure references, as the GPS systems used gave accuracies to within a 6m radius. Where translation to UTM coordinates was unavailable due to programming error in the Newton GPS system, raw GPS latitude/longitude positions are given. An altimeter was used to control estimates of elevation, giving more accurate data than the GPS elevations, and was calibrated each day from the 200m altitude of a base point in Puerto Ibáñez.

The map produced is essentially a lithostratigraphic map, with units mapped according to their similar lithologies and bounded by unconformities, distinct changes in lithology or intrusive igneous contacts. The Ibáñez Formation itself is mapped as a single formation, as although it is a composite unit comprising many volcanic facies and volcaniclastic sedimentary facies, the level of minor faulting within the area mapped precludes mapping the distinct facies as separate minor volcanic formations or members of a larger Ibáñez "Group" with any degree of reliability.

Samples were freighted by road to the SERNAGEOMIN warehouse in Santiago, where they were reviewed at the end of each field season, discarding superfluous material and trimming blocks to size for packing. Boxes of sample were then air-freighted to New Zealand via the United States. Minor problems did occur, with the loss of one box of ammonoid fossils in Chile and the loss of samples when several boxes were smashed open during inspection by US customs officials. During the 1997 field season, fossil samples were carried back as hand baggage to avoid any further losses.

Thin sections for petrology were prepared from 470 samples, and several larger sections were cut for analysis of structural features. Mineral samples of possible economic importance were cut as polished thin sections for both transmitted and reflected light microscopy. Etching the sections with HF and staining for feldspar contents was considered, but rejected because of the high degree of clay alteration and widespread low grade metamorphism. Mineral proportions were visually estimated; in particular, the feldspars were identified by extinction angle methods for plagioclase, and careful examination of refractive indices and 2V measurement for confirmation of albite and checking for K-feldspar presence within the groundmass of some rocks.

Mineral separation was carried out on eight samples to obtain biotite, hornblende and muscovite for Ar-Ar radiometric analysis. Samples were chosen first by field occurrence, with intrusive rocks, tuffs and ignimbrites containing fresh Ar-Ar datable minerals preferentially sampled. Following microscopic analysis, seven samples were chosen on the basis of the occurrence of unweathered biotite and hornblende, and one for the occurrence of secondary muscovite as an alteration of fiamme. Samples were then crushed in a jaw crusher and sieved to appropriate phi-size fractions according to the mineral size ranges noted during microscopic analysis. Crushed and sieved material was then 'cleaned' with a magnet to remove magnetite, after which each size fraction was mixed with solutions of sodium meta-tungstate of measured densities designed to separate out the required minerals, following techniques described by Lewis (1984). Settling took place in separation funnels, and this process had to be repeated several times for each sample, first floating off light feldspars and quartz to concentrate the ferromagnesian minerals, then using denser solutions of meta-tungstate to remove heavy mineral suites while floating the hornblende, biotite or muscovite. After heavy liquid separation, concentrates were washed to remove any residual meta-tungstate and then run through a Frantz magnetic separator to further concentrate the required minerals. Residual meta-tungstate solution and washings were re-concentrated by evaporation for use in the next sample runs. Final selection of mineral grains for irradiation was carried out on the concentrates by hand picking unwanted grains from the concentrate under a binocular microscope. The single muscovite sample was not run through the Frantz separator, instead being hand picked after heavy liquid separation.

Major element geochemistry was carried out by X-ray spectrometry on crushed and ground samples melted at 1030°C and pressed into borate glass fusion beads after the methods of Norrish and Hutton (1969), using both the older furnace and hand-pressed bead method, and later, larger beads from the automated Fusilux process. Trace element X-ray spectrometry was carried out on crushed and ground samples compressed into 40mm pellets bound with poly-vinyl alcohol and acetate. Geochemical data is discussed in Chapter 5 and results are contained in Appendix B.

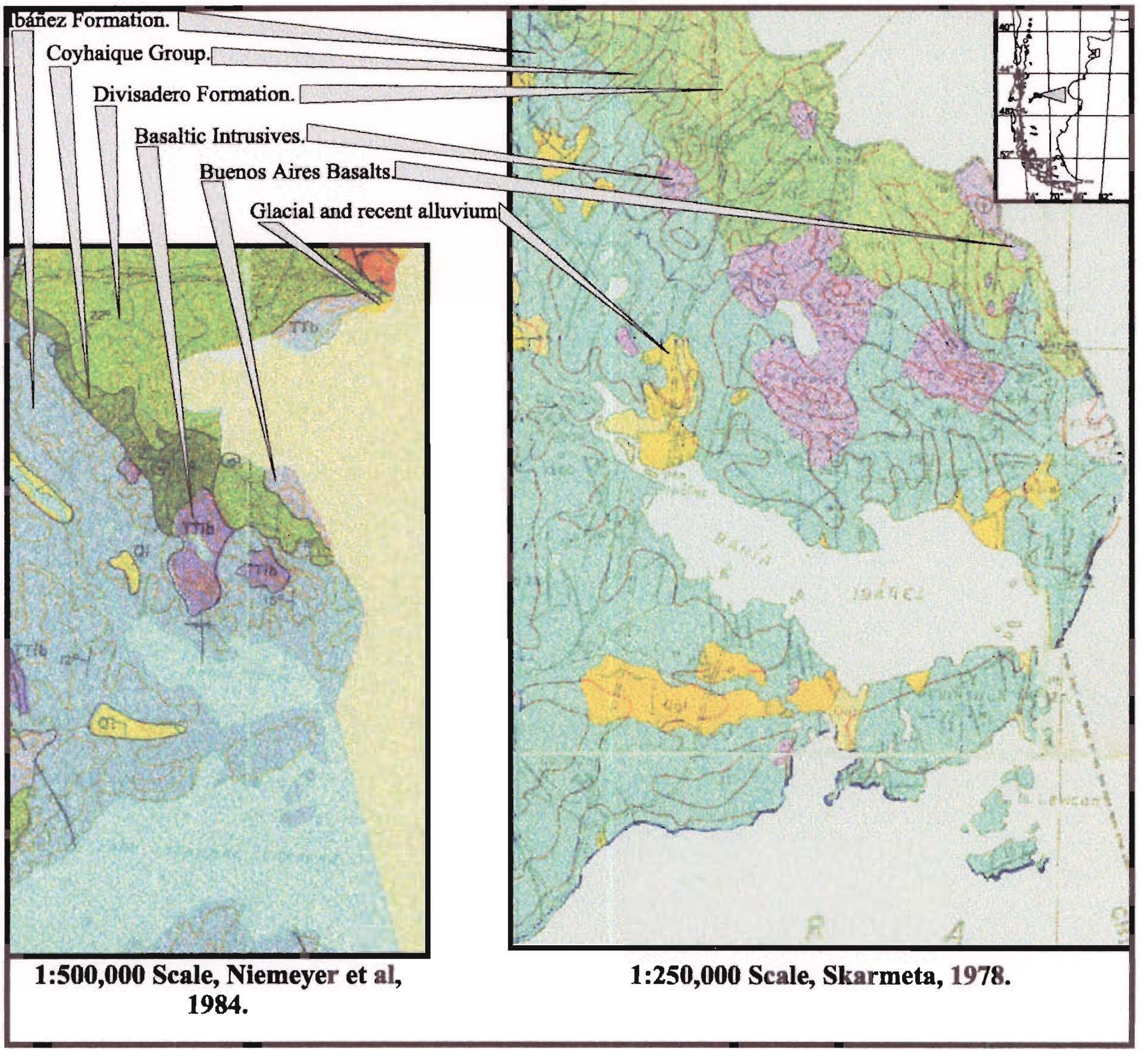

Figure 1.6: Early maps of the Puerto Ibáñez area from the 1:250,000 and 1:500,000 scale maps of Skarmeta (1978) and Niemeyer et al. (1984), respectively.

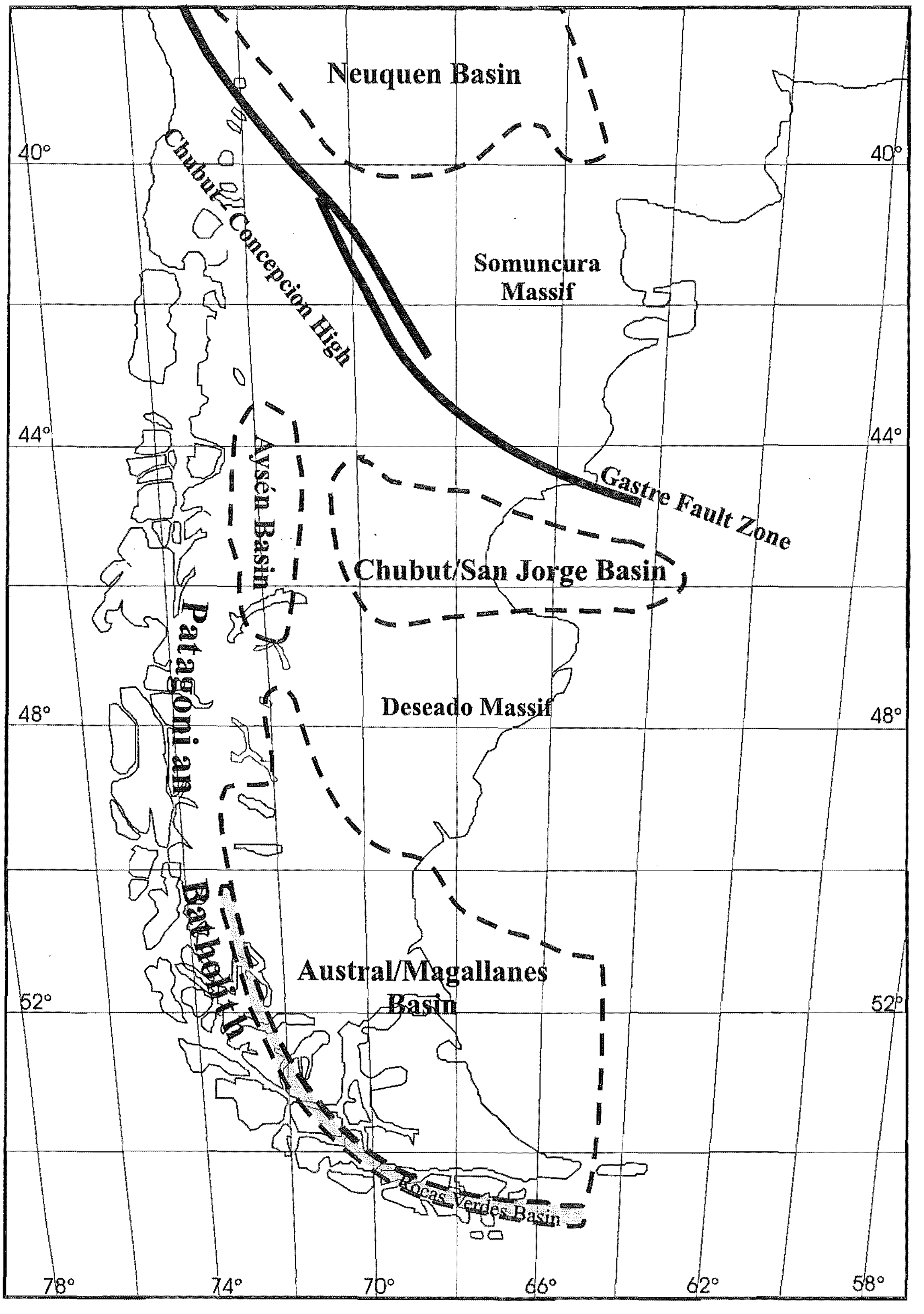

Figure 1.7: Main sedimentary basins of Patagonia, after Riccardi (1988), and other geological features after Pankhurst et al. (1998, 2000).

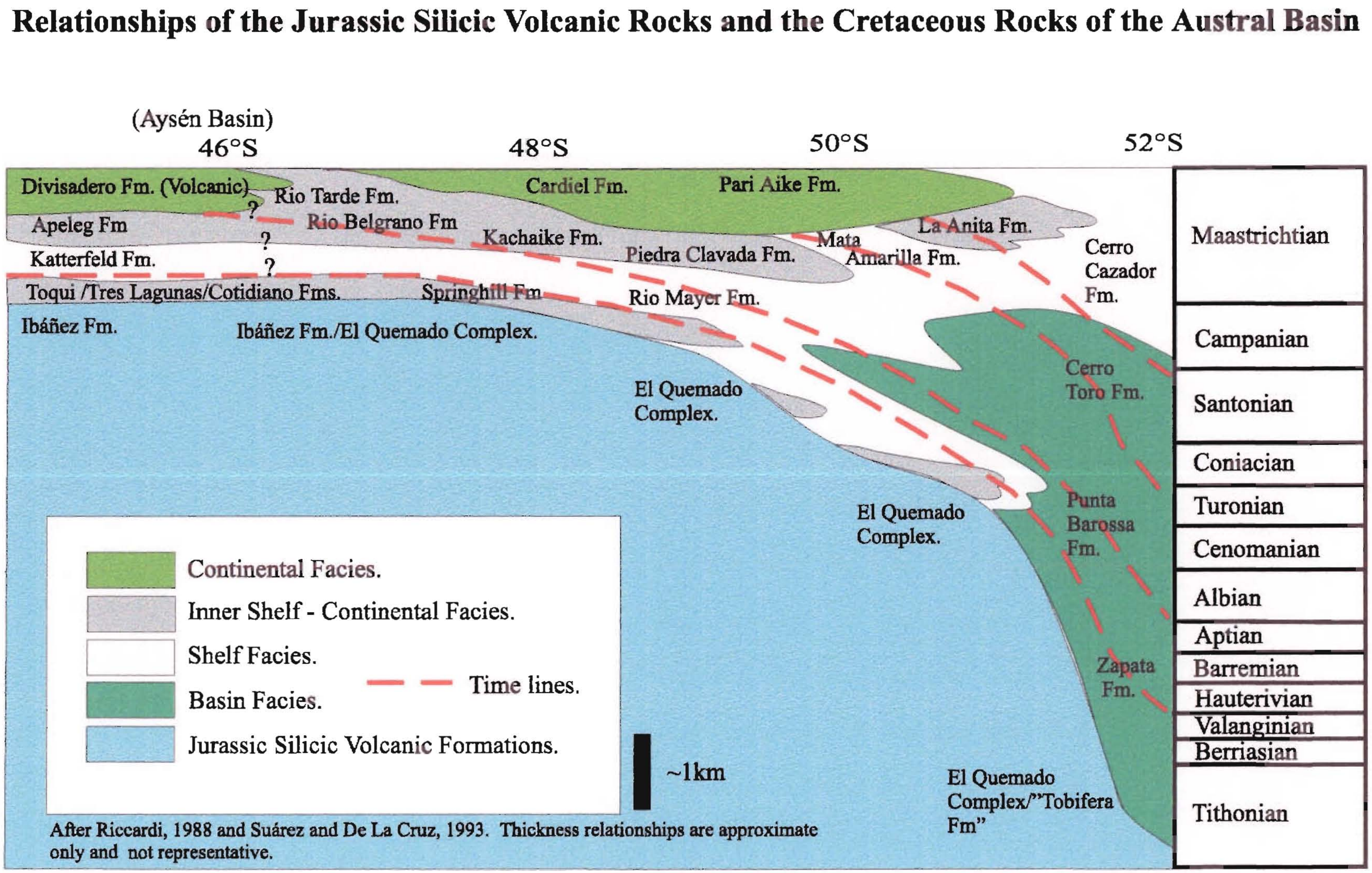

Figure 1.8: Correlation Chart of the Cretaceous Rocks of the Austral Basin, after Riccardi (1988) and Suárez and de la Cruz (1993).

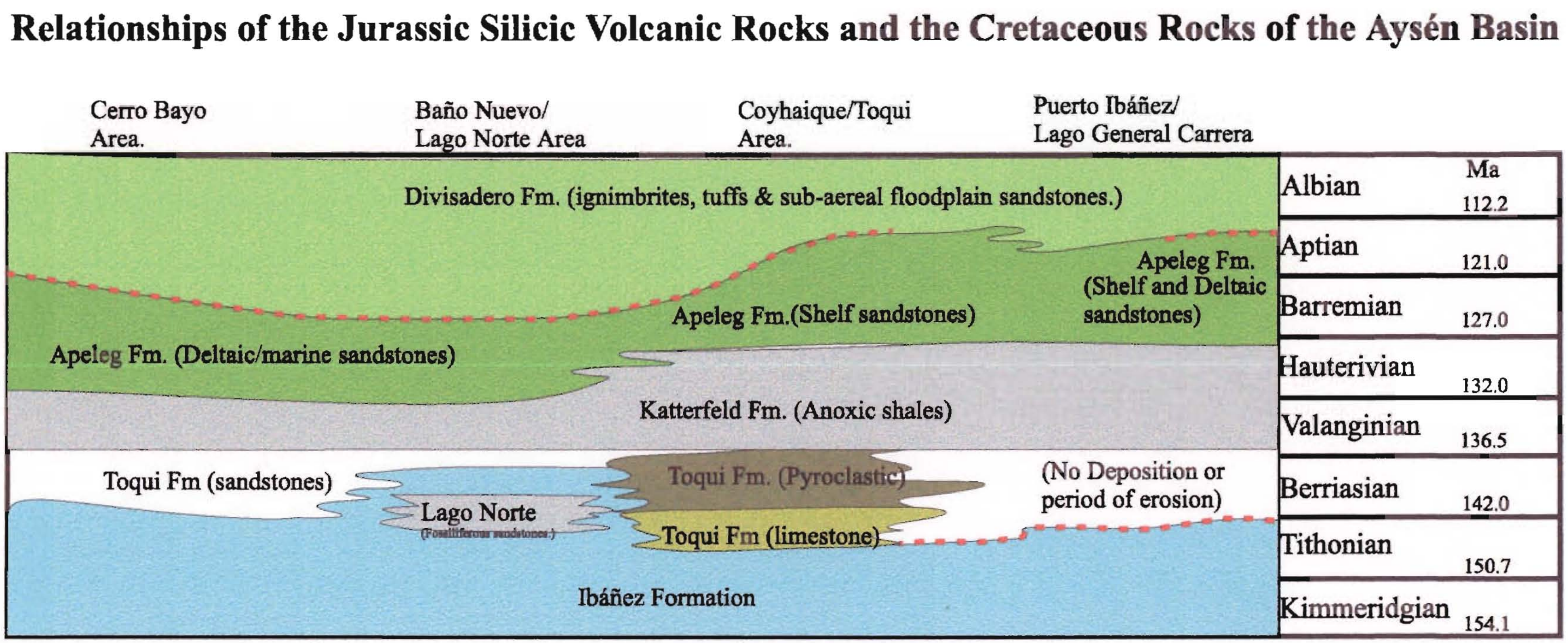

Figure 1.9: Schematic stratigraphic chart of the Jurassic and Cretaceous Rocks of the Aysén Basin, after Suárez and de la Cruz (1994b). Dotted red lines note unconformable contacts.

Chapter 2

Geomorphology

The geomorphology of the Puerto Ibáñez Quadrangle is dominated by the active erosion of glacial landforms created during the successive glaciations of the region from the late Pliocene and throughout the Quaternary. Whereas the higher elevations have close to 100% outcrop available for investigation, many of the lower areas have extensive masking by moraine and fluvial sediments. Geomorphological features and superficial geological deposits are summarised in the accompanying Geomorphology Map (Appendix F).

2.1 Glaciation

Even though the bulk of the area has not been fully glaciated since about 13000 BP or earlier, the area was, at several stages during the Quaternary, well behind the advances of the ice sheets that formed the deep basins of Lago General Carerra and the Rio Ibáñez Valley (Mercer, 1976; Rabassa and Clapperton, 1990). Moraines from these several advances were first mapped by Caldenius (1932) to the east of the Argentinian portion of Lago General Carerra/Buenos Aires. Using 'varve correlation, Caldenius mapped four terminal moraine sequences, of which the inner three were attributed to stages of the Fennoscandian ice sheet of Europe (Daniglacial, Gotiglacial, Finiglacial), whereas the outer moraine was attributed to an older "Initiglacial" stage (Rabassa and Clapperton, 1990). These four moraine sequences were remapped by Morner and Sylwan (1989), who determined five zones containing fifteen terminal moraines, of which only the inner seven moraines, closest to the area mapped in this study, were assigned to the Brunhes magnetic epoch, representing various glacial limits up to 0.7 Ma BP. Of these, only the four innermost were assigned to the last glaciation (Rabassa and Clapperton, 1990). However, further work puts six of these moraines into the last glaciation (Singer et al., 1998). The results of these studies, assigning between four and seven of the major terminal moraines east of the area of this study to the last glaciation, would tend to indicate that the moraines mapped in this study, within the Puerto Ibáñez Quadrangle, can be assigned to the retreat of the last glaciation, or to minor advances of some of the higher mountain glaciers since 12000 BP.

2.1.1 Active Glaciation

The active glaciers are limited to several small cirque glaciers to the northeast of Cerro Farellón (Appendix F). These glaciers are in retreat, and reach no further than the mouths of their respective cirques. The four active glaciers occupy two south facing cirques and two deeper east and west facing cirques on the northeastern area of Cerro Farellón. Their névé areas are small snowfields occupying the head of each cirque above 1800m (See also Fig. 1.5). The snowline in this region is estimated at between 1800m and 1900m (Rabassa and Clapperton, 1990) and none of these glaciers reach below 1500m; they are less than 2 kilometres long.

Beyond their small névé areas, these shallow cirque glaciers melt swiftly, and are essentially semi-stagnant moraine-covered ice tongues with meltwater streams issuing from their snouts, sometimes forming small caves and tunnels beneath the ice (Fig. 2.1).

At the heads of those cirques not occupied by active glaciers, areas of stagnant glacial ice are preserved, surrounded by, or hidden beneath chaotic or hummocky mounds of till and moraine (Fig. 2.2). The floors of these cirques are filled with the final terminal moraines, or occasionally they are clear of moraine and show striated glacial pavements on the bedrock. Small snowfields remain at the head of most cirques, but these are often ephemeral, and appear to have retreated significantly due to increased melting after the Cerro Hudson Ashfall of 1991. Some areas of this chaotic moraine show slight polygonal surface sorting of clasts due to frost-heave.

Figure 2.1: Active glacier snout with meltwater cave opening, northeast Cerro Farellón, GR 2877350 4881900.

2.1.2 Glacial Moraines and Outwash Deposits

Glacial moraines are present in the active and inactive cirque glaciers on Cerro Farellón, and throughout other high alpine areas. The south flank of Cerro Farellón is bordered by a large belt of remnant lateral moraine. The plateau between Cerro Pirámide and Cerro Pico Rojo is covered with moraine and some kettle lakes, and is ridged by a series of arcuate terminal moraines left by a retreating glacial tongue that ran through the notch now occupied by Laguna Huncal.

Moraine is differentiated from outwash gravels by its lack of any obvious stratification, rounding of clasts and sorting, and by the occurrence of sizeable erratic boulders, sometimes exceeding 5m across. Lateral moraines and arcuate terminal moraines are discernable within some moraine fields, (Fig. 2.3), but in the other large moraine area above Estero Largo in the southwest of the field area, moraine occurs as a large irregular sheet or 'spit' of triangular shape, presumably from the confluence of large glacial streams moving

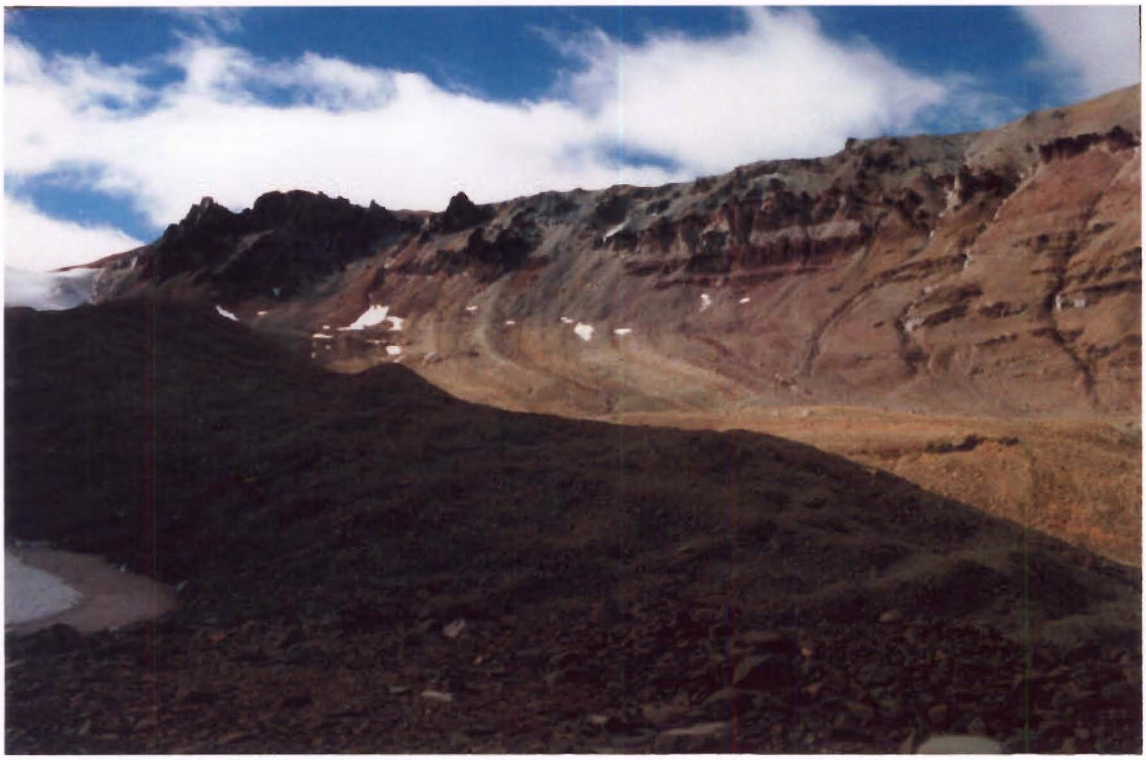

Figure 2.2: Hummocky glacial moraine above stagnant glacial ice on Cerro Farellón. Divisadero Formation forms ridge in background. GR 277250 4882250.

down both the valleys of the Rio Ibáñez and Lago General Carerra (Appendix F). The lower parts of this moraine sheet have been reworked into outwash gravels, with several prominent terraces from Gilbert deltas built into Lago General Carerra during higher lake levels.

Outwash gravels also cover a large area southeast of Cerro Manchón and northeast of Cerro Pico Rojo, and also occur as isolated patches on the east slopes of Cerro Pico Rojo and on the Peninsula Ibáñez. Drumlins and eskers are rare, but do occur occasionally within larger patches of moraine such as that at southeast of Cerro Manchón.

2.2 Alluvial Fans, Debris Fans and Fan-Deltas

Alluvial fans have been built by many of the streams incised into the margins of the glaciated Rio Ibáñez valley. Alluvial fans and debris fans occur at Arroyo Rocoso, Arroyo

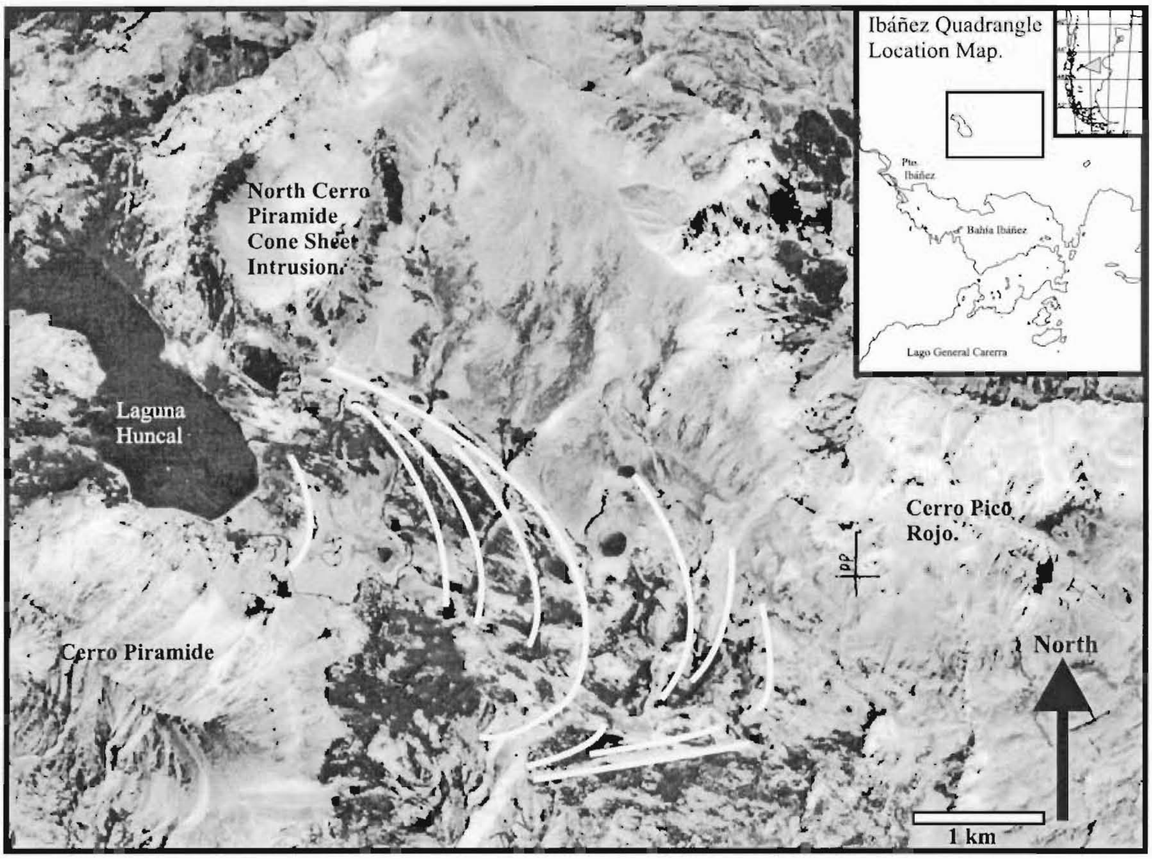

Figure 2.3: Lateral moraines and arcuate terminal moraines (outlined in white) forming ridges on the plateau east of Laguna Huncal. Note also the circular structure of the cone sheet intrusion from the northern extension of the Cerro Pirámide granodiorite.

Huemul, Arroyo Zanjón Feo, Estancia Moroma, Estero Largo and on the coast southwest of Puerto Rey. At Estero Lechoso and Arroyo Zanjón Feo the current streams are in degradation, cutting through large flat-topped alluvial terraces from previous fans and Gilbert deltas deposited at times of higher lake levels. In roadcutting exposures (Fig. 2.4) the topset and foreset beds of these deltas are exposed, showing the typical steep 10-20 degree slope of Gilbert delta type foresets, as developed by river water mixing with standing lake water of similar density ('Homopycnal flow' of Bates (1953)), leading to the bedload of the river dumping out quickly as prograding steep angle dunes and similar rapid settling of the finer sediment as bottomset beds shortly in front of the foreset beds (Boggs, 1987; Elliot, 1978). Similar Gilbert-Delta terrace remnants occur at the margins of the Rio Ibáñez downstream of the waterfalls and bridge over the Rio Ibáñez, and at several levels along Estero Largo, north of Puerto Rey and west of El Maitén. Outcropping portions of these delta terrace remnants are composed of steeply dipping, thickly bedded foresets of poorly sorted, well rounded fluvial sand, gravel and cobble size clasts of local lithologies and batholith derived granitoids. Topping the foreset beds are topset beds of nearly flat-lying coarsely trough crossbedded or channeled sands and gravels of similar type. Although such Gilbert-Delta terraces are common around the shores of the lake, the fine sediments of the bottomset beds are rarely exposed, although some good examples with varving, slump structures and soft sediment deformation features are present in roadcuts between the two bridges over the Rio Ibáñez. The flat upper surfaces of the Gilbert Delta terraces are crossed by dry delta channels, and are generally covered with a thin layer (60cm to 1m) of pale brown or yellow loess. Terrace heights vary, but the highest have foreset heights of up to 50-60m .

Active Gilbert deltas are being built at current lake level by most small streams, and also the Rio Ibáñez and Estero Largo at Puerto Rey, and at two points west down the lake shore from Puerto Rey. The delta of the Rio Ibáñez fills most of the valley downstream of the bridge and waterfalls on the Rio Ibáñez, supplying the best farmland around Puerto Ibáñez. After the influx of debris from the 1991 Cerro Hudson eruption, the delta has expanded such that the ferry landing site at Puerto Ibáñez has been moved 1km east to avoid shoals and bars from the expanding delta.

2.3 Beach and Saline Playa Lake Deposits

Gravel beaches are most common on those portions of the south-facing shore southwest of Puerto Rey, which are subject to strong wave action directed from the western end of Lago General Carrera, whereas sandy beaches are confined to the more sheltered waters of the Bahia Ibáñez. Saline lakes are ephemeral features, and are most well developed on the Peninsulae Ibáñez and Levicán. They generally consist of a brackish or saline lake with sandy shores and thin 'duricrust' surfaces of carbonate and salt deposition for a few tens of metres around the lake or 'laguna.'

2.4 Scree and Rock Fields

Most but not all of the peaks above 1000m within the field area are surrounded by active scree and rock fields, which often continue down to the treeline (which varies between 900 and 1100m).

On Cerro Farellón and Cerro Manchón, frost heave keeps scree and rock fields active on all slopes except those below glacial ice or covered by moraine deposits. Southwest of Cerro Manchón, at the northern margin of the large landslide into Estero Lechoso, there is a sizeable moraine deposit which appears to have become a slow moving rock glacier fed by the screes above it. Stagnant scree areas are rapidly overgrown by alpine shrublands and later grasslands once sufficient soil has accumulated. Higher areas of stagnant or partially active scree derived from well bedded rocks have some development of platy imbrication of clasts. Polygonal frost heave textures are evident in some areas (particularly on the southwest area of Cerro Farellón).

Cerro Pirámide, Cerro Pico Rojo and Cerro Cabeza Blanca lack the extensive scree fields of the more massive peaks. However, in general the main outcrops of each peak are surrounded by active scree and rock fields which follow the lines of the underlying intrusive or rhyolitic dome rocks that form the cores of these three mountains, with scree aprons concealing the lower contacts (Fig. 2.5).

2.5 Landslides and Rockfalls

Active landslides occur in two places, one immediately southwest of Cerro Manchón into the headwaters of the Estero Lechoso, and another below the southwest face of Cerro Pico Rojo. Rockfalls are common throughout the field area, but prominent active rockfalls are found at Estancia Moroma and in the Rio Ibáñez valley.

At Cerro Manchón, a large landslide of approximately two square kilometers is collapsing westwards off the face of Cerro Manchón, towards the middle reaches of Estero Lechoso. The landslide is moving on several planes of collapse within water saturated blackshales of the Katterfeld Formation, and is carrying on its upper surface a carapace of at least two back-rotated blocks of the overlying stratigraphy (i.e. upper Katterfeld Formation, Apeleg Formation, and redbeds of the lower Divisadero Formation) as well as part of a trachytic sill which intrudes these rocks (Fig. 2.6). Remnants of other blocks are left on the lower surface of the landside toe as a scattering of debris, the bulk of them having been eroded off by Estero Lechoso and other streams. This landslide, aside from its size, is important as within it occurs the only major fossil location mapped in this area. The toe of the landslide is being undercut by several streams, mainly Estero Lechoso, and these may contribute to its continued instability. At the front of the landslide, smaller mudslides and landslides spall off the main slide during the winter and spring thaw, when the shales reach maximum water saturation.

Southwest of Cerro Pico Rojo, a smaller landslide is active in the head of Estero Saltos, where the stream undercuts an area of hydrothermally altered Divisadero Formation. Alteration of the Divisadero tuffs to bentonitic clays on which the slide is moving was probably associated with the either the intrusion and eruption of the Cerro Pico Rojo Rhyolites, or with the intrusion of the basaltic sills which underly part of the rhyolitic dome complex.

Rockfalls, in both the Ibáñez and Divisadero Formations, such as those at Arroyo Zanjón Feo, Estancia Moroma and Rio Ibáñez, are associated with past or active stream erosion at the foot of sizeable bluffs of ignimbrite or tuff with pre-existing fracture systems. The fall in the Rio Ibáñez, in particular, is facilitated by west-inclined joint sets within the thick sequence of ponded ignimbrites. Erosion from the Rio Ibáñez has undercut the bluff and the rockfall is still seasonally active, feeding a large scree slope and debris field. At Estancia Moroma, the rockfall is currently driven by erosion from a small stream, although the size and orientation of the bluff over which the stream currently flows indicates that the original undercutting was probably glacial in origin. At the eastern end of this fall, towards Estancia Moroma, a landslide is active in the lower parts of the Divisadero Formation and the upper Apeleg Formation.

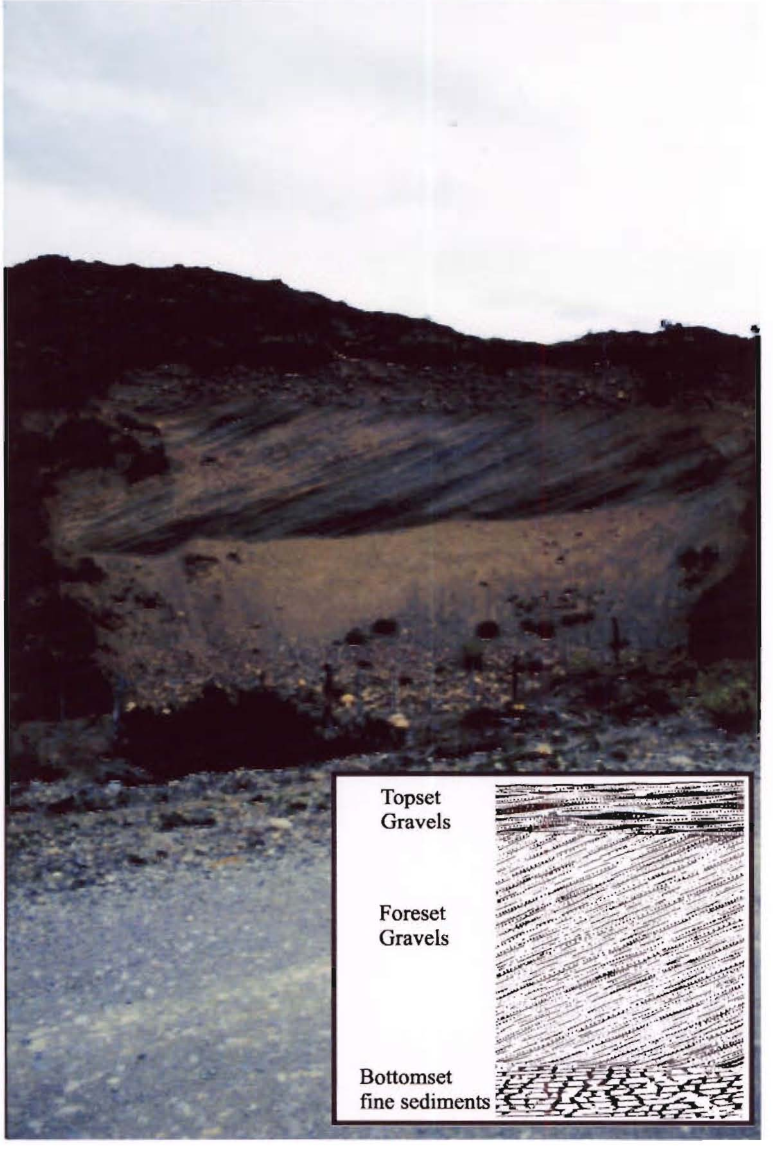

Figure 2.4: Terrace with the upper parts of Gilbert Delta foreset crossbedded gravels and thin topset trough crossbedded gravels and sands exposed in roadcutting above Puerto Ibáñez, GR 274400 4871600. Inset shows example of the facies sequence left by a prograding Gilbert Delta, from Elliot (1978) after Gilbert (1885)

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Figure 2.5: Scree apron around Cerro Pico Rojo rhyolite dome complex, with orange and red stained rhyolite scree fields. Leña forest and arcuate terminal moraine ridges occur in foreground. Photo taken looking east from GR 2806890 4872200.

Figure 2.6: Back-rotated block of Apeleg Formation in scree-covered headscarp of the landslide to the southwest of Cerro Manch6n. Note fractured appearance and steeper dip angle (30° east) than that in the in situ Apeleg Formation sandstones to the left of the frame, dipping at 4° to the east. Pack in foreground is 60cm in height. GR 278751 4879246.

Chapter 3

Stratigraphy

This chapter gives an overview of the stratigraphy and facies in the main mapping area at Puerto Ibáñez, with additional information from outcrops and measured sections in the basement to the south and west, and in the Cretaceous rocks to the northwest near Coyhaique. As the Ibáñez Formation is inferred to unconformably overlie paleozoic basement through most of its outcrop extent, a review of the closest examples of the underlying basement rocks is given, mainly for comparison with the few basement xenoliths present in the Ibáñez Formation. The nearest accessible basement outcrops are near Puerto Tranquilo, and also from Lago Cochrane, Lago Esmeralda and Puerto Guadal. The Ibáñez Formation is not described as a coherent stratigraphic unit, but rather a faulted unit with disrupted internal stratigraphy. Consequently I discuss the various facies associations and rock types that can be found within the Ibáñez Formation, rather than a stratigraphic section. The overlying Cretaceous rocks have a simpler structure. The Cretaceous stratigraphy, particularly of the Divisadero Formation, in the Puerto Ibáñez-Cerro Farellón Quadrangle will be compared to measured sections in the type area around the Coyhaique region (Cerro Divisadero, Cerro Montreal, Lago Frio). Intrusive rocks will be dealt with according to their composition and stratigraphic relationships, i.e.: granodioritic and tonalitic microgranitoids cutting the Ibáñez and Divisadero Formations, or basaltic hypabyssal rocks cutting the Divisadero Formation.

The stratigraphic description is intended to illustrate the geological development from the upper Jurassic until the middle Cretaceous rocks within the Aysén Basin see Figs.1.7, 1.9).

3.1 Basement Schists and Marbles

Basement rocks, ranging from mildly deformed greywackes to phyllites underlie the Ibáñez Formation outside the mapped area. These rocks are inferred to underlie the mapped area from the presence of similar lithologies as accidental lithic fragments in tuffs of the Ibáñez Formation and as xenoliths in intrusions hosted in the Ibáñez Formation and overlying rocks. The locations visited are from the well-exposed schists to the south and west of Lago General Carrera (Fig. 3.1). The basement rocks of the Aysén region and areas further south are not well known, but have been suggested to be a composite set of Paleozoic accretionary prism and fore-arc basin assemblages accreted to the region by progressively southward displaced subduction active during the Paleozoic (Mpodozis and Ramos, 1989; Ramos et al., 1986).

Cochrane and the road south of Lago Esmeralda

At Cochrane, low grade shale/phyllites underlying lower Ibáñez Formation were sampled. A brief investigation was carried out south of Cochrane, in basement rocks which vary from greywacke sandstones with little cleavage development and simple upright folds, through to phyllites and quartzo-feldspathic schists showing evidence of multiple complex deformations, in the space of some 10km.

In the Cochrane outcrop studied at location SCH1(46°13'58"S, 72°37'1"W), the basement is weathered semi-pelitic and pelitic phyllites and schists, interlayered with or cut by quartz veins and late stage crenulation cleavages. These rocks are overlain unconformably by weathered blue tuffs of the Ibáñez Formation. Below the unconformity, the basement schists are fine grained micaceous or pelitic schists and phyllites, interlayered with, and cut by, quartzose veins, with a schistosity oriented at 188°/24°, itself folded by crenulations and and an incipient crenulation cleavage trending 070° and plunging 20°E. These structures are cut by kink-band folds, trending at about 205° (see Fig. 3.2). The quartz/mica layering and crenulation cleavage surfaces appear folded by larger folds, to which the later kink bands display vergence relationships; these folds are tight, upright

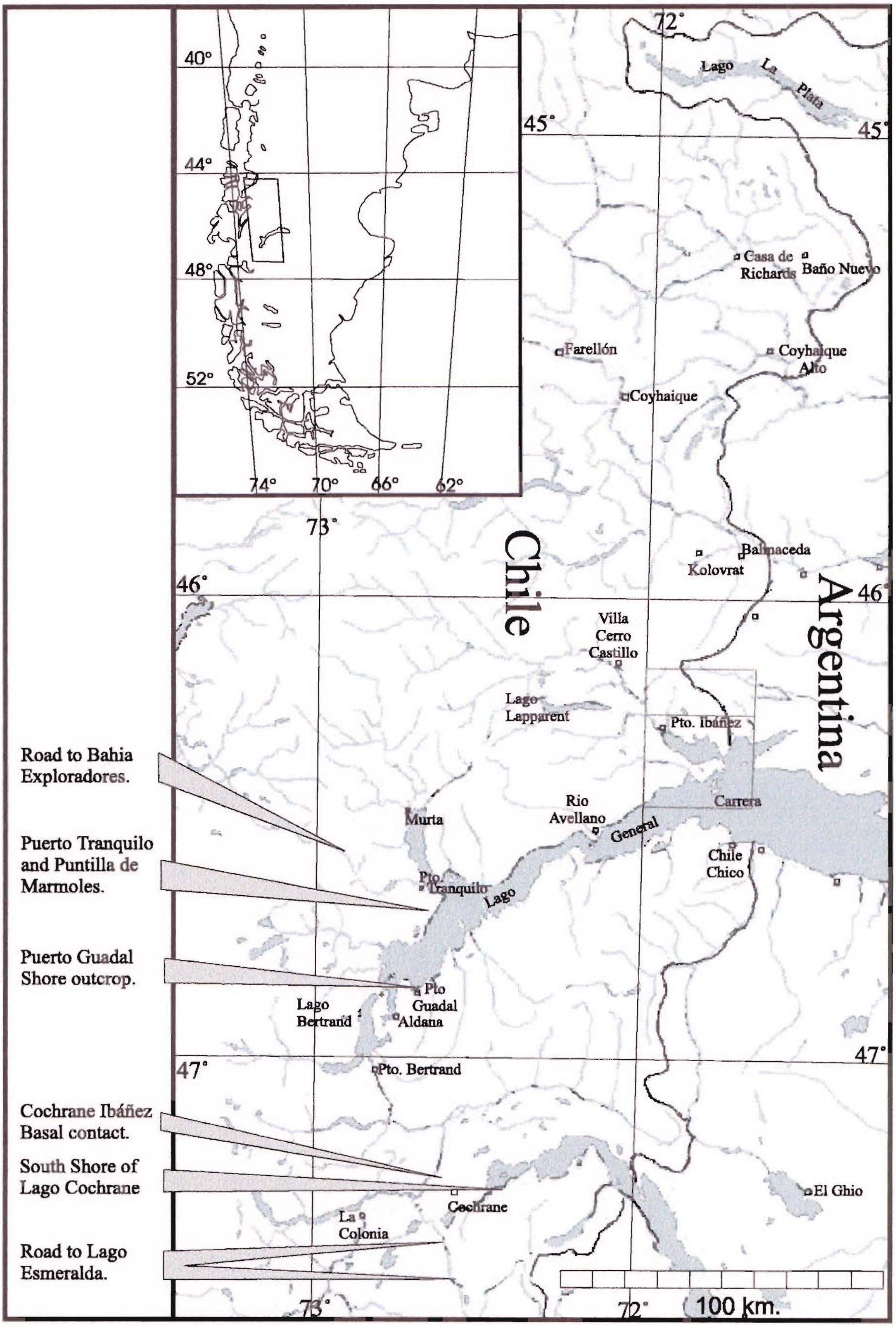


Figure 3.1: Location map for basement outcrops visited to the west and south of Puerto Ibáñez.

Figure 3.2: Fine grained micaceous pelitic phyllites underlying the Ibáñez Formation at Cochrane, showing crenulation cleavages and kink-band folding. Pencil is 15cm high. Approximate location: 46°13'58"S, 72°37'1"W.

folds with a near vertical axial planar orientation trending 200° - 205°.

The contact between the Ibáñez Formation and the Basement in the Cochrane section is relatively simple. The upper few metres of schist are weathered and cracked, and are overlain by a weathering horizon of 15–20 metres of yellowish clay, with weathered blocks of volcanic origin, plus calcite and agate veins. Weathering of both the volcanic clasts and blocks of dissaggregated schist is spheroidal, with Fe and Mn oxide staining present on cracks and joints between and within blocks. This weathering horizon is interpreted as the local unconformity surface on which the early Ibáñez Formation was erupted. In this location, Ibáñez rocks are dull duck-egg blue lithic tuffs and grey-blue ignimbrites with poorly developed columnar jointing.

South of Cochrane, on the road to Lago Esmeralda, brief investigation of roadside schist outcrops showed a wide difference in the structural complexity and metamorphic grade of the basement in the Cochrane-Lago Esmeralda region.

At the furthest south of these outcrops, exposed in the river at 47°28'5.9"S, 72°32'17.4"W,

Figure 3.3: Upright similar synform fold in massively bedded fine and medium sandstone metasediments, south of Lago Esmeralda. 47°28'5.9"S, 72°32'17.4"W.

the basement consists of dark medium and fine sandstones, thickly bedded and of low metamorphic grade. These sandstones are folded in simple, upright to moderately plunging similar folds, both antiforms and synforms, to which a poorly developed schistosity is axial planar (072°/90°) (see Fig. 3.3). The folds plunge at about 45° NE in some outcrops, and are overprinted by sets of kink bands orientated at about 320°/70°, with a sinistral sense of deformation, east over west. There is little evidence of more than one major deformation, with no segregation layering, or even evidence of much new mineral growth, except for sparse quartz veins (which may include prehnite-pumpellyite facies minerals) developed parallel to the kink bands.

However, slightly further north along this road, at 47°23'57.1"S, 72°35'13.8"W, schists exposed in a glacially smoothed roadside outcrop show an early schistosity developed close to the remnant bedding structure, seen in the west of the outcrop, picked out by pelitic and quartzose schist layers. The earlier schistosity is overprinted by a later schistosity which develops from kink bands. Figure 3.4 shows the relationship between the earlier

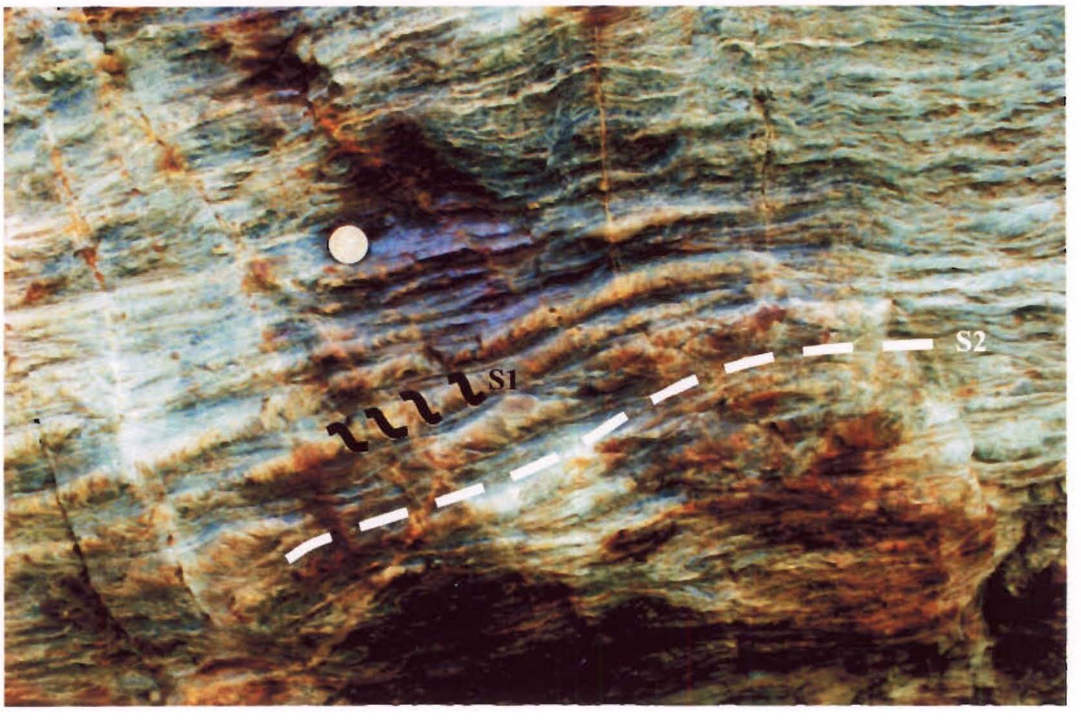


Figure 3.4: Kink bands and associated schistosity (S2) partially overprinting an earlier schistosity (S1) visible as quartzose remnants within kink bands. Coin is 15mm across. 47°23'57.1"S, 72°35'13.8"W.

schistosity, and the later kink band schistosity, which becomes dominant in the east side of the outcrop a few metres away (attitude 232°/60°). In turn, this second deformation schistosity is cut by quartzose segregation veins. This level of deformation is significantly more intense than that described at the southern end of the Lago Esmeralda Road, yet is only some 10km further north.

Continuing this apparent trend of increased structural complexity towards the north and east, on the new road to Bahia Vidal, along the south side of Lago Cochrane, 47°16'21.3"S, 72°28'1.2"W, the schists and phyllites show possible basin and dome folding, with fold axes of the second generation running about 191°, plunging 12° S, refolding kink band folds approximately perpendicular to the secondary folds; the second generation folds have vertical or subvertical axial planes, but their trend varies by up to 20 degrees within a few metres.

Puerto Guadal

Further north at Puerto Guadal on the southern shore of the southwest end of Lago General Carrera, the lakeshore wave cut platforms on the headland (46°50'20"S, 72°42'0"W) are of greenschists with evidence of multiple deformations. Tight isoclinal folds in marbles occur within the greenschists, and some outcrops show these isoclines to be sheath folds which have been re-folded (see Fig. 3.5).

Bahia Exploradores road outcrops

Phyllite and marble outcrops occur throughout this area, bounded to the west by the South Patagonian Batholith, and unconformably overlain by isolated outliers of lower Ibáñez Formation tuffs. Outcrops studied are from road cuttings south of Puerto Tranquilo, and a rough transect taken in road cuttings along the new road to Bahia Exploradores which was under construction to the west of Puerto Tranquilo (Fig. 3.6).

Investigation of these rocks was carried out briefly on two days. Starting the furthest west from the roadhead, a brief transect through the basement close to or in contact with the batholith was taken.

Location SCH2, on the Bahia Exploradores road: (46°33'17"S, 72°54'16"W) This location was closest to the roadhead when visited in the 1997 field season. Freshly broken and blasted road cuttings, scarred by blasting drillholes allow good examples of the contact with local granodiorites. The basement rocks here are very altered, with a massive dark grey to black outcrop of amphibolitic appearance with poor gneissic schistosity, and veined with white quartzose/granitic layers which suggest *lit-par-lit* style intrusion of material from the nearby granitoid (see Fig. 3.7). Minor disseminated sulphides occur (generally pyrites). The granitic veins are 1–30cms wide, and the gneissic schistosity is complexly folded, with fold axes approximately orientated at 160°/80°, but this layering is disrupted and sometimes destroyed by the *lit-par-lit* style granitic veining.

On re-visiting this location during the 1998 field season, the roadhead had advanced some kilometres beyond the 1997 position, so the attribution of the alteration and *lit-*

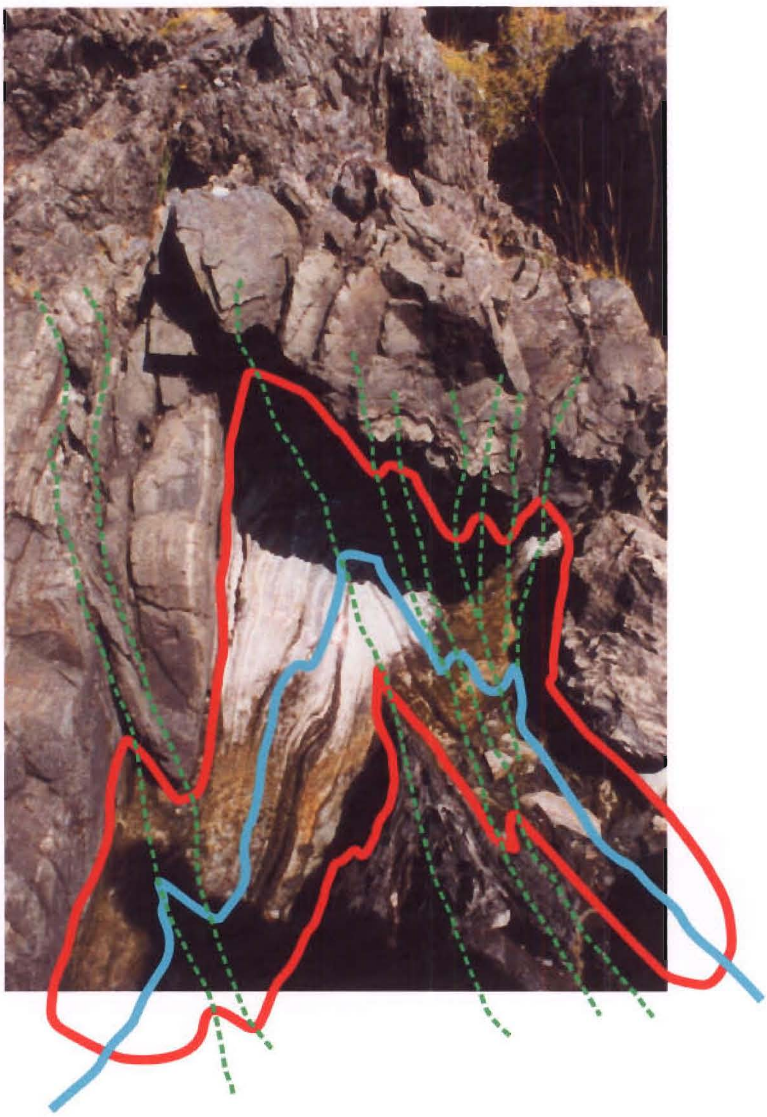


Figure 3.5: Refolded sheath folds of marble in calc-silicate schists and greenschists on the beach platform at Puerto Guadal, Lago General Carrera. Red outline indicates sheath fold in marble with closures off field of view of photograph. Blue line shows folded axial plane of sheath, while dotted green lines show axial planes of small kink folds refolding the sheath fold. View approximately 2.5m across. 46°50'20"S, 72°42'0"W.

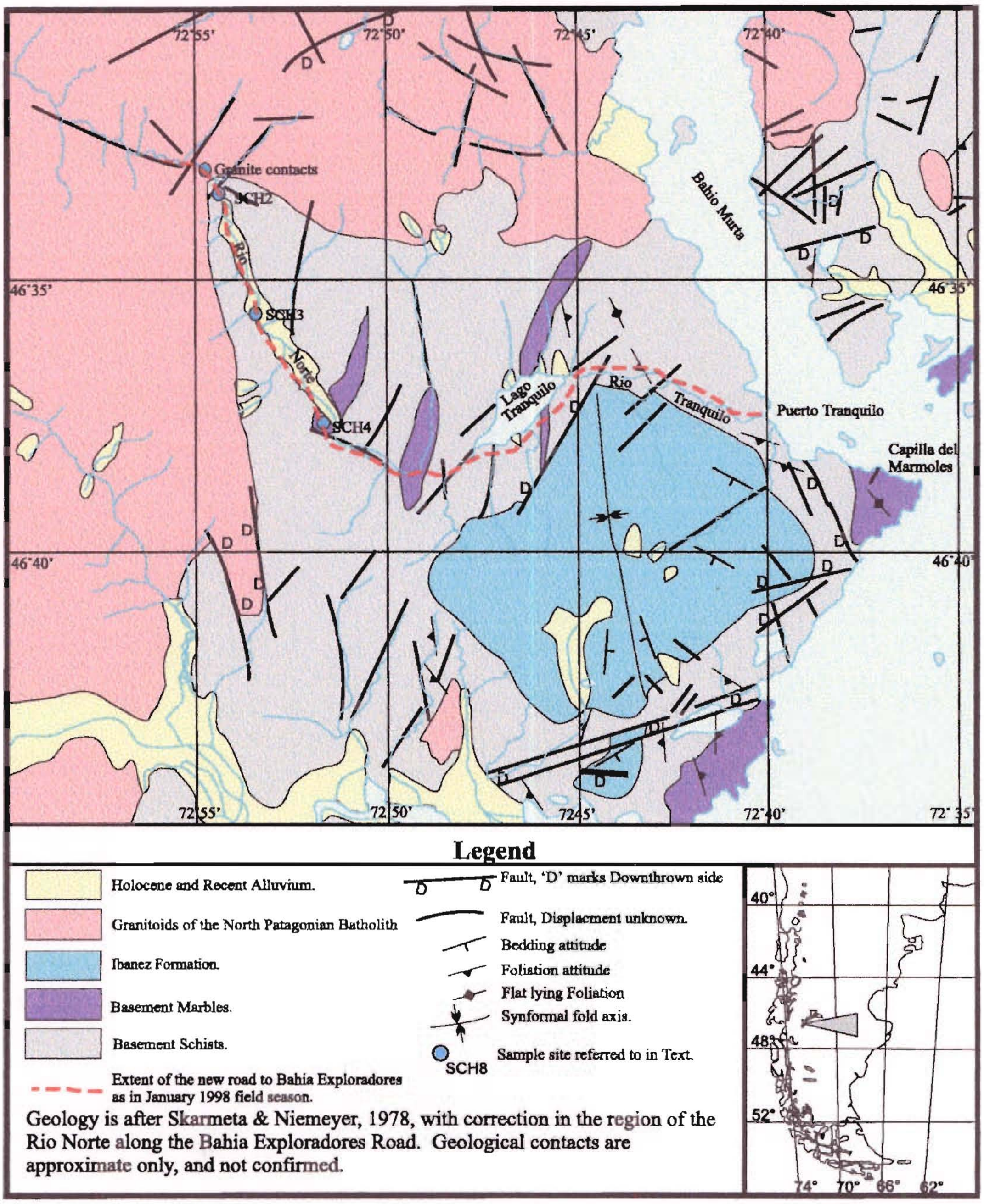


Figure 3.6: Geological sketch map of basement outcrops visited on the Bahia Exploradores road, after Skarmeta (1978).

Figure 3.7: Amphibolitic gneiss veined with ***lit-par-lit*** injection layers of granitoid, Bahia Exploradores road, west of Puerto Tranquilo. 46°33'17"S, 72°54'16". Hammer is 0.5m high.

par-lit injection structures of the SCH2 outcrops by nearby granitoid intrusions was confirmed by the occurrence of granodioritic rocks slightly further along the road at latitude 46°32'53"S, longitude 72°54'43.2"W.

Location SCH3, (46°35'37.6"S, 72°53'29.6"W): Leaving the roadhead and moving east back towards Puerto Tranquilo, one leaves the strongly altered contact aureole of the granitoids behind and moves into schists and phyllites with lenses of marble and calcic schists. At Location SCH3, basement rocks are monotonous grey phyllites and pelitic schists, with very fine grained muscovite mica dominant over quartz. The schistosity is crenulated and folded, with trend varying from 220° to 265°, and fairly uniform plunge of 35°W.

Location SCH4, (46°37'3.5"S, 72°51'46.9"W): At this point along the road transect, a large lense of marble is intercalated within the schists and phyllites, forming an approximately northward trending band, at least 1km thick, and several kilometres long. The marbles are white and grey, and are intercalated with calcic and pelitic schists, with many

Figure 3.8: Marble pod within grey phyllites on the Bahia Exploradores road, showing minor folds with vergence structures indicating an antiform to the east. 46°37'3.5"S, 72°51'46.9"W. Hammer is 0.5m high.

subvertical shear zones present between schist and marble. These marbles and schists display minor folds with an axial planar surface orientated at approximately 315°/51°, with the fold plunging almost directly down dip at 45° to the west. The shear zones present near the contacts between marble and schist layers trend 002° and plunge 80° N (see Fig. 3.8). Marble layers are weakly cleaved and break parallel to the schistosity of adjacent schist bands. The vergence relationship of minor folds within the schists and marbles, and their relationship to the cleavage indicates that this location is on the western limb of an antiform, with the hinge zone close to the east. Slightly further south, the cleavage is nearly vertical, trending 020°. The marbles were sampled for microfossils but later proved barren (Bradshaw (1998) pers comm.).

Further south at location SCH4 B, (46° 37'3.5"S, 72° 51'47"W) a schist band within the marble (orientation 210°/85°) is the first occurrence of soft, green calcic schist, again with the schistosity parallel to the banding in the marble layers. Minor folds still show vergence towards a hinge zone in the east, although the folds in the marble are tight, similar folds, tighter than the crenulation folds in the schists at SCH4. Schists along this transect can be estimated, from field mineralogy, to be lower greenschist grades, somewhat higher than the schists at Cochrane and south of Lago Esmeralda.

Puerto Ibáñez

No outcrop occurs, but basement rocks are found as lithic fragments within many tuffs and ignimbrites, and were occasionally present as rafted blocks within minor intrusives south of Estero Largo. Basement xenoliths or lithic fragments within rocks in the Ibáñez Quadrangle are usually small lapilli to large blocks included in tuffs and ignimbrites, or rafted blocks within intrusions. They are crenulated, coarsely crystalline quartzites and greenschists with quartz/albite/muscovite/chlorite. The underlying rocks in the Ibáñez Quadrangle are inferred to be part of the same or similar terranes to the more complex basement types reviewed above, as the lithic fragments of schist present in the Ibáñez Formation are most similar to schists from the more complexly deformed basement exposed in the Puerto Guadal,Puerto Tranquilo, Bahia Exploradores Road, and Lago Cochrane locations, rather than the less metamorphosed deformed pelitic schists and metagreywackes from the Cochrane and Lago Esmeralda outcrops.

3.2 Ibáñez Formation

3.2.1 Silicic Pyroclastic Rocks

These rocks comprise the bulk of the Ibáñez Formation, and consist of a wide variety of airfall tuffs and ignimbrites, and occasional lapilli tuffs, lithic tuffs, and breccias. Thick tuffs of probable ignimbritic origin are common throughout the area, but occur most often in the Rio Ibáñez valley, the Peninsula Levicán and the Peninsula Ibáñez. Lithic tuffs, possibly lithic lag breccias, occur to the south of Cerro Pirámide, at El Maitén and at Puerto Rey (see Fig. 3.9), either as discrete layers intercalated with tuffs and ignimbrites, or as lenses within tuffs and ignimbritic rocks. Accretionary lapilli in tuffs are rare, compared to their common occurrence in the younger Divisadero Formation. In the West Ibáñez and Rio Ibáñez areäs, the occurrence of intercalations of shales and fine grained water-laid rocks suggests standing water (see Fig. 3.25).

Whereas some of the pyroclastic rocks are still in situ around silicic domes (for example, those at Cerro Farellón, Cerro Cabeza Blanca and the Peninsula Levicán), and can easily be interpreted as block and ash/breccia aprons, much of the outcrop extent of tuffs and ignimbrites that define the Ibáñez Formation cannot be associated with any specific vent structures. These rocks may be interpreted as either extra caldera tuff/ignimbrite outflow sheets or, in areas of thick accumulations of well developed ignimbrites such as the Rio Ibáñez valley, as valley ponded or caldera filling sequences. However, the pervasive minor faulting makes correlation of any one eruptive complex difficult if not impossible (see Fig. 3.9).

Ignimbrites

Ignimbrites are found throughout the mapped area, and vary from a few metres to greater than 100m thick; occasionally, individual units can be traced for several kilometres before outcrop is cut off by faults. Thin, 5 to 10m thick tuffs and ignimbrites are often altered to a light blue colour by pervasive alteration of matrix material and pumice fiamme to clays, sericitic muscovite or chlorite. Thicker ignimbrites also commonly show chlorite, sericite and and clay alteration of pumice, but the matrix is often less weathered and retains a mauve colour. Sericitic muscovite from altered pumice fiamme from a thick (15–20m) ignimbrite on the Peninsula Ibáñez returned a Jurassic Ar-Ar age (see Chapter 6) indicating alteration coeval with or shortly after Ibáñez Formation volcanism. Simple cooling features are often present, with some units from both Peninsula areas displaying columnar jointing within the core of the ignimbrite (Fig. 3.10), but tops and bases are of massive, unjointed material, or with flaggy, bedding parallel jointing or cavernous weathering features, reflecting a possible lack of primary welding. Lithic fragments are sparse, and generally small.

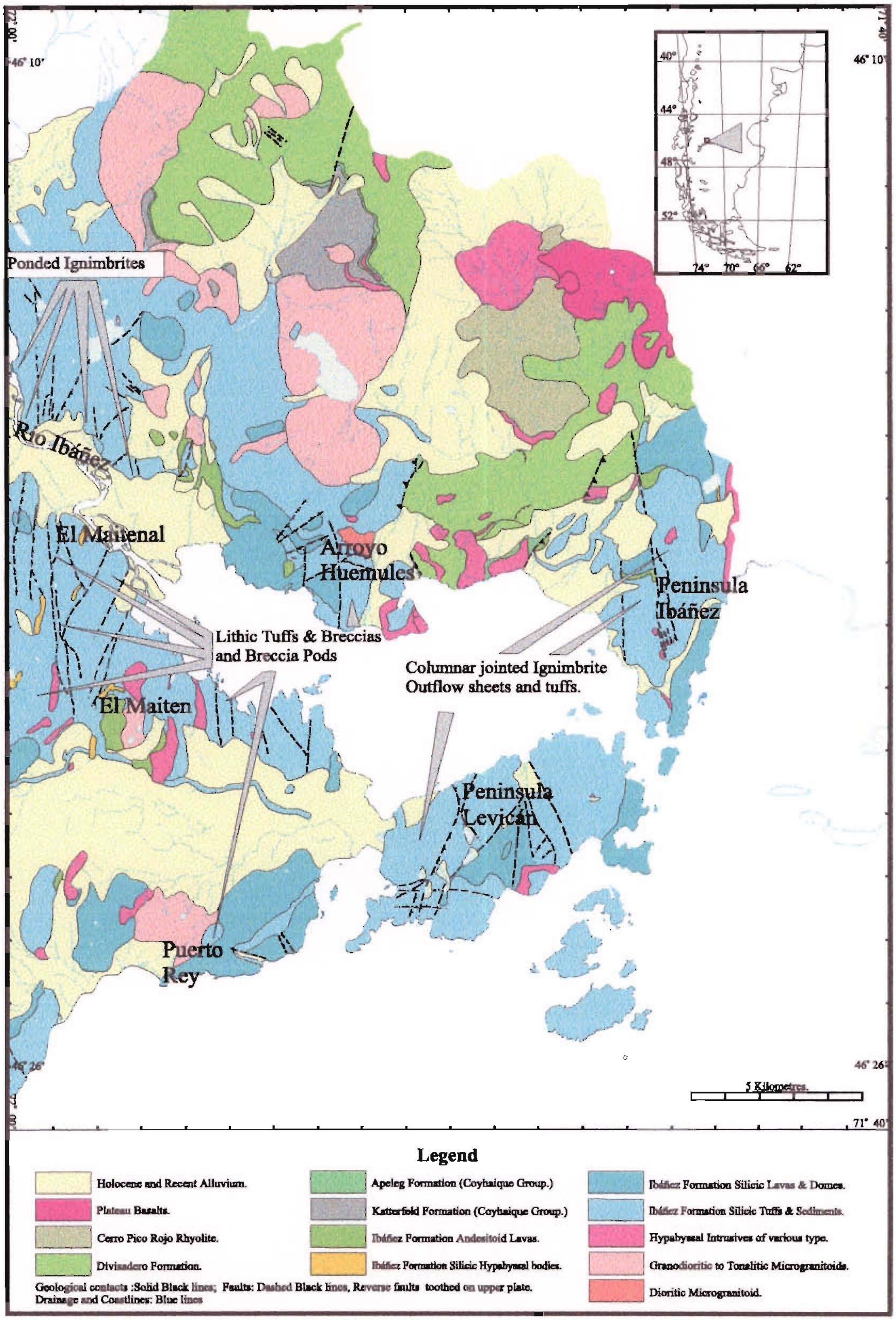


Figure 3.9: Location map areas of Tuff, Ignimbrite and Lithic Tuff/Breccia units in the Ibáñez Formation.

Figure 3.10: Columnar jointed ignimbrite forming ridge on Peninsula Ibáñez. Columnar zone is about 4.5m high, and is topped by a massive flaggy or fissile zone with rounded weathering form. GR 278814 4866912, looking north.

Ponded Ignimbrites

The thickest ignimbrites in the Puerto Ibáñez area outcrop to the northwest, in the east bank of the Rio Ibáñez itself. These ignimbrites are massive, poorly bedded units displaying no columnar jointing, and are up to 130m thick. Intercalated between the large ignimbrites are volcaniclastic sandstones displaying graded bedding and load casts, as well as smaller ignimbrite flow units, crystal tuffs and debris flows. The thick ignimbrites are underlain by finely laminated silts and blackshales, indicating the presence of lakes between eruptive episodes and ponding of ignimbrites in topographic depressions, which may be caldera related.

A measured section through a 130m thick ignimbrite on the eastern bank of the Rio Ibáñez at GR 271625 4871575 (Fig. 3.11) shows a relatively monotonous unit, underlain by tuffs and reworked tuffaceous sandstones. There is little internal structure apart from zones of pumice and lithic concentration in the lower part of the tuff, and some degree of crystal enrichment and lack of lithic fragments in the upper part. Both below and above this outcrop, a further two more ignimbrites of similar size occur, also intercalated with reworked tuffaceous material and debris flow units. Ignimbrites of similar size occur slightly further south above the road into Puerto Ibáñez itself, underlying the units exposed at GR 271625 4871575. None of these thick ponded ignimbrites show any development of columnar jointing or large fiamme, which may indicate a lack of primary welding and cool deposition temperatures.

Lithic Tuffs and possible Lag Breccias

Lithic rich units are found throughout the Ibáñez Quadrangle, but are noticeably more common in the central and south-western parts of the field area, from Arroyo Huemul across the Bahia Ibáñez to the area between Rio Ibáñez, Estero Largo and El Maitén. These vary from lithic concentration zones within tuffs and ignimbrites, to large, massively bedded, matrix-poor polymict breccias 5-10m thick, with angular clasts ranging from 1-2cm lapilli through to blocks up to 2m across.

Lithic rich lenses or breccia lenses within tuffs and ignimbrites can be seen at Puerto Rey (see Fig. 3.12), where lithic rich laminated tuffs include lenses of matrix poor lithic breccia with gradational contacts. The occurrence of these coarse lithic lenses within tuffs and ignimbrites may suggest lithic dumping proximal to eruptive centres. However, some breccias do not occur with ignimbrites, and show rounded clasts and association with graded deltaic sandstones, and may be either deltaic debris flow related or due to lahars (those at El Maitenal), whereas others are monomictic breccias associated with silicic lavas.

Surge Deposits

Much of the Ibáñez Formation is composed of thin (less than 3m) tuffs and tuffaceous sandstones, intercalated with the main cliff forming units (ignimbrites and rhyolitic lavas). Whereas many of these units show a high degree of alteration, internal structures are

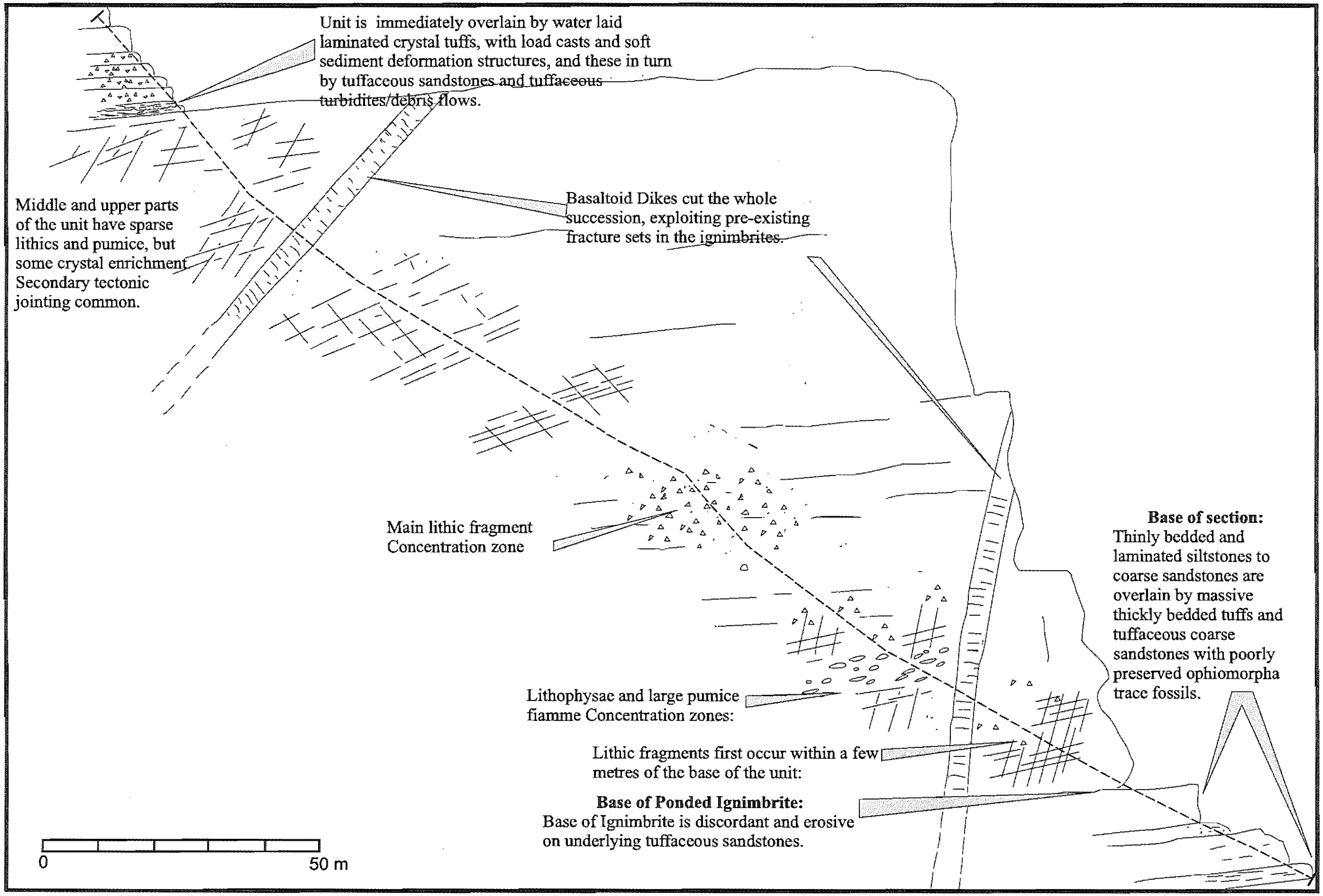


Figure 3.11: Measured section of a 130m thick ponded ignimbrite intercalated with reworked crystal tuffs and volcaniclastic debris flows in the Rio Ibáñez valley at GR. 271625 4871575.

Figure 3.12: Coarsely bedded lithic lag breccia lenses in tuff at Puerto Rey, varying between occasional lapilli and blocks in tuffaceous matrix, to matrix-poor clast supported polymictic lag breccias of angular clasts from small lapilli to blocks exceeding 1m. Outcrop is 12m high. GR 275570 4587710, looking northeast.

preserved in some places. On the southern side of the Peninsula Levicán at GR 282080 4858590, a fault bounded block of tuffs and epiclastic sediments contains laminated tuffs with low angle antidune type cross stratification and lapilli to cobble sized lithics. These suggest emplacement as surge or blast deposits. At this locality one tuff shows internal erosion surfaces indicating a turbulent flow environment, with each emplacement unit has eroded into earlier deposited material.

Pinch and swell bedding characteristic of surge deposits is not often present, but can be seen in the tuff and breccia apron of the silicic lava dome at Cerro Cabeza Blanca described earlier (see Fig.3.18). The Puerto Rey Dome Complex of dacitic lavas also includes remnants of a carapace of thinly bedded lithic tuffs that may be surge deposits associated with either initial dome eruptions or block and ash dome collapse eruptions.

Accretionary Lapilli Tuffs

Accretionary lapilli are not commonly found preserved in the tuffs of the Ibáñez Formation, generally due to the destruction of much of the internal vitroclastic and sedimentary textures by devitrification followed by varying degrees of lithification and thermal recrystallisation of ashy material. However, some accretionary lapilli can be seen as faint ghost images on weathered surfaces in both massive and bedded tuffs from the Peninsula Levicán, and as well preserved examples southwest of Cerro Farellón, in tuffs associated with a rhyolitic dome scree/breccia apron (Fig. 3.13).

3.2.2 Silicic Extrusive and Subvolcanic Rocks

Silicic extrusive rocks are present as three major dome complexes (Southwest Cerro Pirámide, Puerto Rey, and Cerro Cabeza Blanca — dated at 150.3Ma), as faulted fragments and as minor dome complexes on the west side of the Bahia Ibáñez (West Ibáñez Rhyolites), of both dacitic and rhyolitic lithologies. Subvolcanic intrusive rhyolitic bodies, some of which are peperitic, occur on the western side of the Bahia Ibáñez. The rhyolitic rocks along the eastern edge of the Peninsula Ibáñez and eastern tip of Peninsula Levicán

Figure 3.13: Accretionary lapilli (arrows) in thinly bedded tuffs associated with remnant rhyolitic dome lavas and breccias at southwest Cerro Farellón. Hammer head measures 15cm. Near GR 273686 4876447, at about 900m.

(Frontier Rhyolite, seeFig. 3.14) may be included here, as their structures and textures indicate more a cryptodome/subvolcanic environment than a hypabyssal origin.

Extrusive Silicic Domes and Lavas

Lavas and domes consist of blocky, flowbanded rocks, with common breccia zones, and fringing remnants of stubby coulée lavas, breccia aprons or block and ash deposits. Faulted dome rocks that occur at southwest Cerro Pirámide are intercalated with tuffs, ignimbrites and andesitic lavas. Faulted domes on the Peninsula Levicán retain an apron of block and ash deposits to their southern side. Cerro Cabeza Blanca has pre-cursor tuffs and surge deposits with distinctive pinch and swell bedding underlying the breccias and coulée flows which spall off the main dome. On the south-western shore of the field area, in the Puerto Rey dome complex, rhyolitic and dacitic dome lavas display complex internal flowbanding and autobrecciation. Most of the domes are without columnar jointing, more often displaying contorted flowbanding, brecciation and sheeting joints. Well developed columnar jointing was only seen in one small, weathered cryptodome in the West Ibáñez Rhyolites (see Fig. 3.14).

Peninsula Levicán Dome/Lava Remnants

These rocks form a fault bounded triangular slice across the centre of Peninsular Levicán (see Fig. 3.14). The fault zones are eroded out and occupied by small saline lakes and slope colluvium, or trapped glacial moraine and lake sediments. To the west and east the dome is faulted against Ibáñez Formation tuffs and ignimbrites, and to the southwest against Ibáñez Formation tuffaceous sediments and minor debris flows. The southeast margin is an intrusive contact with an andesitic minor intrusion with unusual compositional layering (alternating andesite and trachy-andesite layers between one and two feet thick). The northern three quarters of the triangular area consists of porphyritic dacitic lava, with phenocrysts of quartz and calcic oligoclase in a fine grained flowbanded felsitic matrix. Flowbanding is contorted and chaotic, but in the cross sections drawn (see Fig. 3.15) can be seen to dip generally to the east. Taken with the fairly low aspect ratio of the outcrop, and the underlying/adjacent block and ash tuffs and breccias, the dip suggests this outcrop is part of a coulee lava rather than an eroded dome remnant. Coherent rock is occasionally cut by bands or patches of auto-brecciated rock, interpreted as remnants of autobrecciation zones between dome or coulee flow septa (Bonnichsen and Kauffman (1987)) (Fig. 3.15).

The southern quarter of the triangle contains a remnant of an apron of breccias or block and ash deposits. These rocks are generally monomict, containing angular lapilli to block and bomb size clasts of the flowbanded dacitic lava rock, and range from matrix poor clast supported breccias through to matrix supported block and ash deposits (Fig. 3.16). Both breccia and block and ash deposits form a fringe along the southern edge of the triangle of dacitic rocks, dipping to the south at about 30°, and are inferred to underly much of the Peninsula Levicán lava flow.

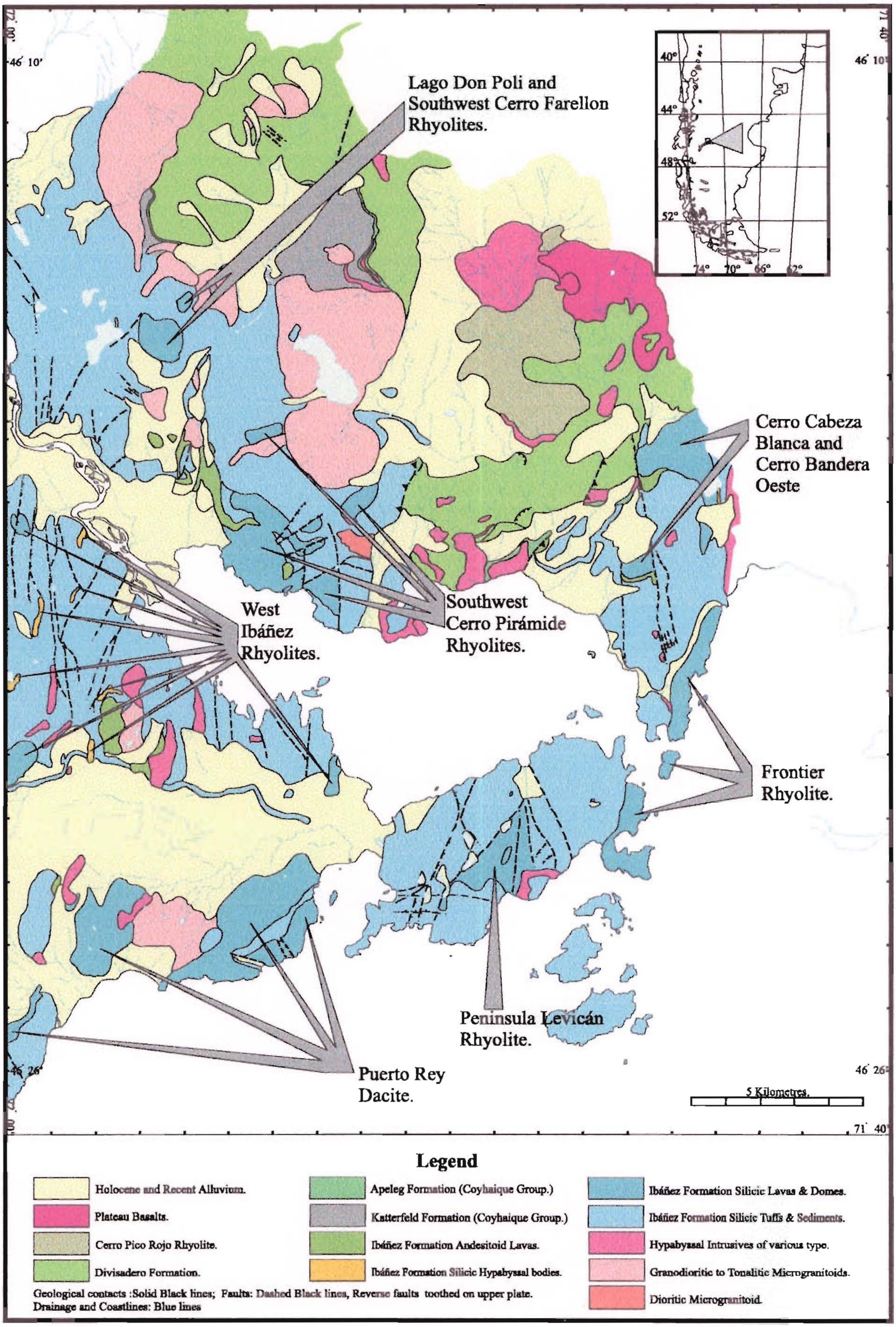


Figure 3.14: Location map of silicic lavas and domes of the Ibáñez Formation.

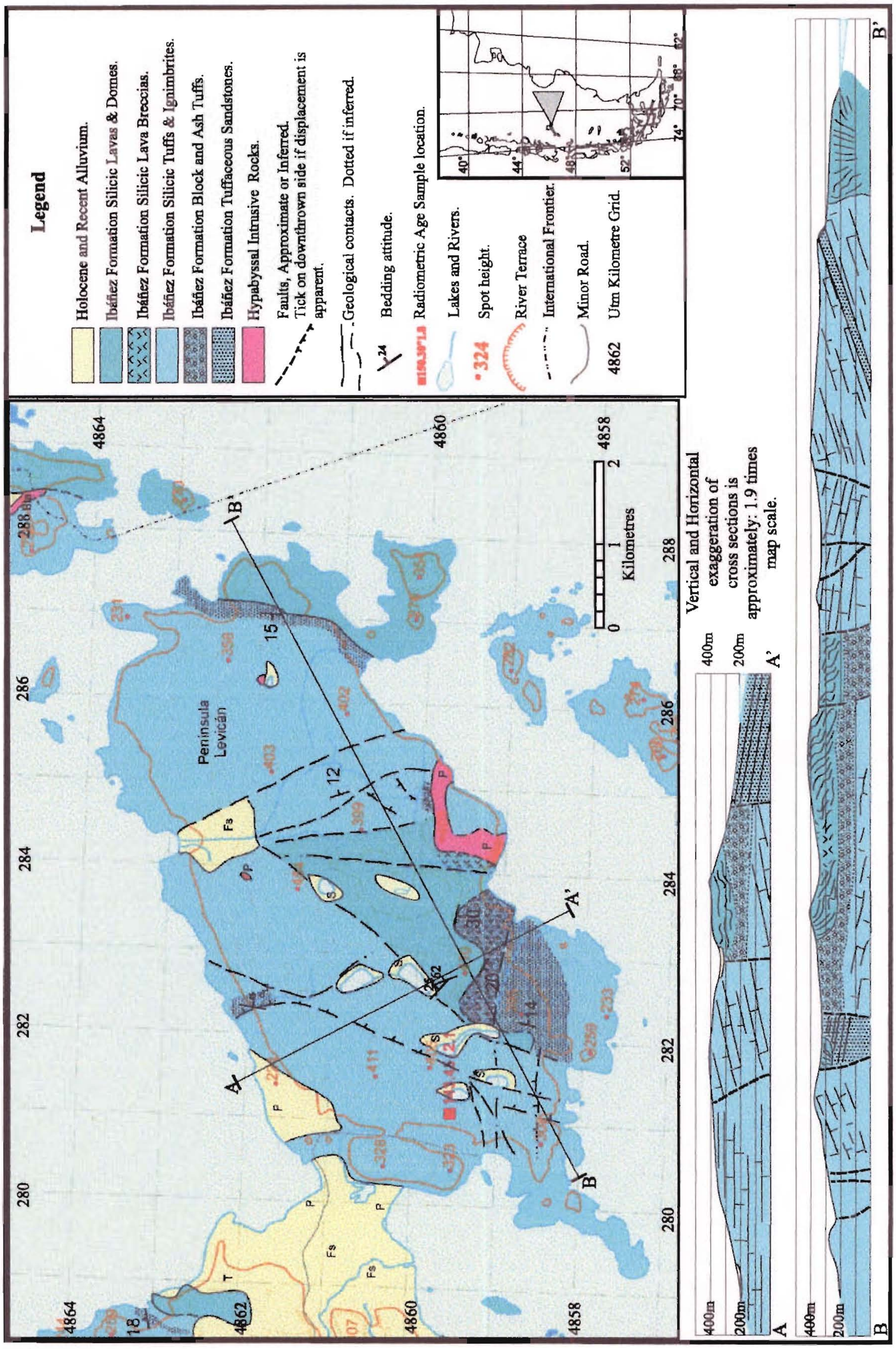


Figure 3.15: Cross sections of the rhyolite lava flows exposed on Peninsula Levicán.

Figure 3.16: Rhyolite cobble in block and ash deposit, Peninsula Levicán. Pencil is 15cm high. GR 283424 4859525, looking south.

Cerro Cabeza Blanca Dome

Cerro Cabeza Blanca, a small mountain immediately north of Laguna la Pollolla and the border crossing to Argentina is a very well preserved rhyolite dome, occurring at the very upper part of the Ibáñez Formation. It retains remnants of an apron of surge deposits plus block and ash flows in Arroyo Zonjón Feo immediately to the west of the mountain, and a fragment of coulée lava flow faulted 2km sinistrally to the south at Cerro Bandera Oeste (Fig. 3.17).

The dome has been partially dissected on its southern face, immediately north of the border crossing. Below the dome a thick, columnar jointed feeder dike cuts through weathered upper Ibáñez Formation tuffs onto which the dome was erupted (see Fig. 3.17). Rhyolite sampled from the core of the dome here on its south side returned a biotite Ar-Ar age of 150.3±1.8 Ma, (Late Jurassic, Tithonian-Kimmeridgian boundary) while K-Ar from the same sample gave 155±2.8 Ma (see Chapter 6). At its base the dome cuts through and is erupted discordantly onto dark brown and purple weathered and clayey

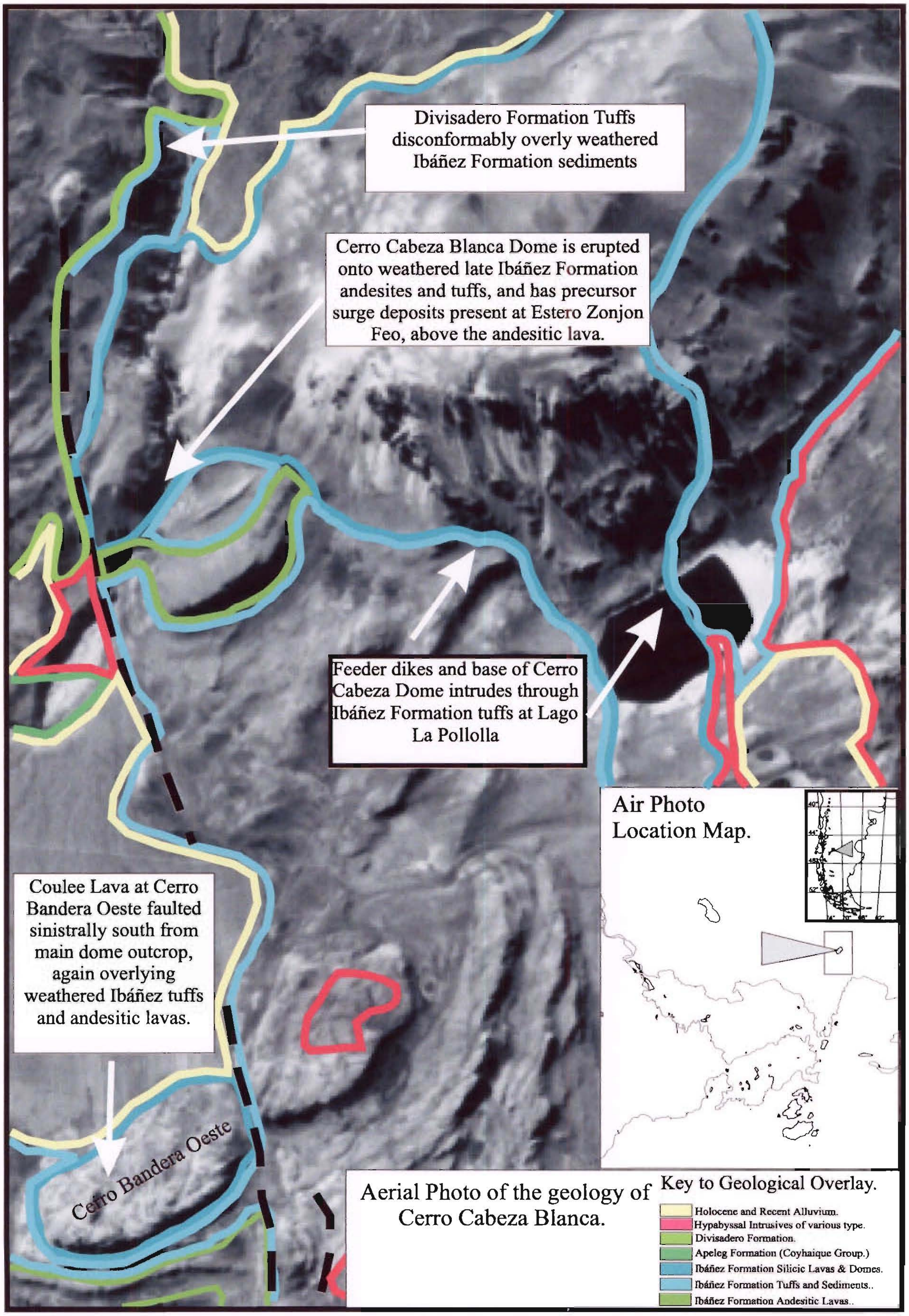


Figure 3.17: Air photo with sketch overlay of the geology of Cerro Cabeza Blanca.

tuffs, lithic tuffs and ignimbrites, and to its western margin the dome apron surge deposits, breccias and a coulee lava overlie similar tuffs and an andesitic lava. The faulted coulee lava fragment at Cerro Bandera Oeste also overlies weathered tuffs and another andesitic lava (Fig 3.17).

The dome only retains parts of its apron of surge deposits, block and ash deposits and stubby coulee lavas at the western margin, and these are best exposed in Arroyo Zonjón Feo (see Location Map, Fig. 3.17). Here, coarsely laminated to thinly bedded rhyolitic tuffs unconformably overlie the brecciated upper surface of an andesitic lava and a small patch of weathered and clayey blue Ibáñez Formation tuffs. The rhyolitic tuffs show low angle cross stratification, pinch and swell bedding, and normal and reverse grading of altered pumice fragments (Fig. 3.18) and can be interpreted as pyroclastic surge deposits (Cas and Wright, 1993). Upstream closer to the dome, the tuffs are overlain by massive monomictic rhyolitic breccias of pink spherulitic and flowbanded rhyolites (Fig. 3.19). However, the coulée lava overlying these breccias is cut by a fault immediately west of the dome, and the bulk of the lava has been eroded out by the stream. On the east of the same fault, a similar lava is exposed two kilometres to the SW at Cerro Bandera Oeste, where the lower part of a coulée flow and its underlying breccias survive (see Fig. 3.17), and is likely to be part of the same dome and lava complex. At this location the lava and breccias have flowed over weathered Ibáñez Formation tuffs and tuffaceous sediments, as well as part of an andesitic lava (Fig. 3.20). The rhyolite flow is missing its upper parts, but retains the flow core of pink spherulitic rhyolite and blocky green and white weathered flow base breccias.

The core of the Cerro Cabeza Blanca dome is composed of pink, mauve or red flow-banded rhyolite with 2–3mm euhedral phenocrysts of sericitised feldspars and occasional bipyramidal quartz. To the northeast and north it is overlain unconformably by tuffs, lithic tuffs and breccias associated with the Divisadero Formation. The dome comprises spherulitic rather than flowbanded rhyolites, with phenocrysts of feldspar, quartz and biotite.

Figure 3.18: Pinch and swell bedding with low angle cross stratification in pink and green pumiceous rhyolitic surge tuffs underlying the rhyolite dome at Cerro Cabeza Blanca. Hammer to bottom right is 0.5m high. GR 287300 4871600, looking north.

Figure 3.19: Monomictic rhyolitic breccias from the Cerro Cabeza Blanca rhyolite dome coulée lava.

Figure 3.20: Cerro Bandera Oeste, with four successive ridges of: weathered purple Ibáñez Formation tuffs; an andesitic lava flow; surge tuffs from Cerro Cabeza Blanca; coulée lava from Cerro Cabeza Blanca. GR 287521 4867918, looking north.

Puerto Rey Dome Complex

Rocks of this dome complex outcrop in the hills around Puerto Rey (see Fig.3.14). The outcrops are sparse, as many contacts are hidden by patches of moraine or raised beach gravels from highstand periods of the lake. There are three main areas of silicic extrusive rocks here, those at Puerto Rey itself, and a further exposure further southwest along the lakeshore near the margin of the Puerto Ibáñez Quadrangle.

In the field, these dacitic rocks are readily distinguishable from the other silicic lavas of the Ibáñez Formation in this region by their distinctive colour and mineralogy. In hand specimen they are porphyritic rocks with a phenocryst population of between 20 and 30% of 1–3mm plagioclase and altered green mafic minerals, often glomeroporphyritic, in a dark red-brown or mauve groundmass. When weathered, the groundmass alters to a greenish grey, with patches of chlorite, and the feldspars take on a pinkish hue. Unlike the more Silicic lavas of Puerto Ibáñez, Cerro Cabeza Blanca and West Ibáñez regions, the rocks at Puerto Rey lack quartz phenocrysts and spherulitic textures, although they are sometimes flowbanded, with areas of alternating flowbanding and autobrecciation.

Southwest Cerro Pirámide Rhyolites

A series of faulted remnants of rhyolitic domes occur on the lower southwest slopes of Cerro Pirámide. This dome complex is the most altered and disrupted of those mapped in the Puerto Ibáñez area. The rocks are cut by numerous small faults, and have been thermally altered by the close proximity of dioritic and granodioritic intrusions associated with Cerro Pirámide itself. The dome fragments and faulted coulée lavas outcrop southwest of Cerro Pirámide as pale white, flowbanded rocks with fine flaggy jointing and some contorted flowbanding; there are also occasional faulted remnants of weathered, purple spherulitic rhyolite lavas. The rhyolites in the main area occur from the lake level up to an altitude of approximately 400m, and are intercalated with tuffs, lava flow breccias and epiclastic sediments, as well as being cut by many small faults, fracture zones and dikes. Above these rhyolitic lavas are further tuffs, breccias and ignimbrites, cut by dikes and the Cerro Pirámide granodiorite. Another rhyolitic dome, retaining some breccias and intercalated with lithic tuffs and ignimbrites, occurs at about 1200m on the high south shoulder of the mountain at GR 279000 4870500. Further to the north on the western faces of Cerro Pirámide a rhyolitic dome at about 800m, GR 2876000 4872100, has no lava flows or breccias, and is possibly cryptodome or hypabyssal rhyolitic intrusion.

Lago Don Poli Rhyolite Plug and Southwest Cerro Farellón rhyolites

Two rhyolitic domes occur in the Cerro Farellón area. One is a cryptodome with intrusive contacts and no breccia apron or lava flows above Lago Don Poli. The other is a small fragment of a pale white silicified rhyolite dome with some associated breccia aprons and accretionary lapilli tuffs, below the southwest peak of Cerro Farellón. All of the rhyolitic rocks in the Cerro Pirámide to Cerro Farellón area have a moderate to high degree of alteration due to the close proximity of the Cerro Pirámide and Cerro Farellón intrusions, and are often pale and leached, or spotted with epidote and pyrite. They are host to minor sulphide bearing veins with traces of pyrite, quartz, galena and chalcopyrite. In particular, mineralisation was noted on Cerro Farellón at GR 273873 4876304, where the altered rhyolitic lava and nearby tuffs and breccias are cut by gossanous quartz veins bearing goethite, pyrite, sphalerite and galena. The mineralisation occurs in veins and breccias closely associated with dikes and small sills of porphyritic microgranitoids of the Cerro Farellón intrusive complex.

West Ibáñez Minor Rhyolitic Intrusives, including Cryptodomes and Peperites

Small dome fragments, flow breccias, dikes, sills and irregular stocks of pale white, yellow or purple weathered rhyolite, either porphyritic with sparse quartz and plagioclase or aphanitic and flowbanded, occur throughout the western Ibáñez Quadrangle. In particular these outcrop near El Maitenal, and in the block faulted tuffs and breccias between El Maitenal and El Maitén. A flowbanded rhyolitic plug or hypabyssal rhyolite intrusive is cut by Estero Largo immediately southwest of the andesites at El Maitén, and a larger portion of a rhyolite dome occurs near the western edge of the mapping area north of Estero Largo at GR 270150 4862670 (see also Fig. 3.14). Two smaller rhyolitic bodies west of the Rio Ibáñez at El Maitenal and to the southeast on the coast at GR 278700 4862900, north of Puerto Rey, lack features associated with subaerial dome extrusion. Instead, these rocks often have smooth, sinuous contacts with country rock, coherent internal flowbanding and a lack of brecciation. Some of these units have intruded into wet and unconsolidated volcaniclastic sediments, resulting in a glassy chilled margin and a surrounding envelope of hyaloclastite mixed with disrupted sediment. A peperitic dike also occurs slightly west of GR 270190 4868460, where a thin (<1.5m) rhyolitic dike has intruded unconsolidated and wet Ibáñez Formation tuffs and sediments, resulting in disruption of bedding and a carapace of disrupted sediment and hyaloclastite around the dike for up to 1m.

Frontier Rhyolites

These rocks form a linear outcrop running down the eastern edge of the Peninsula Ibáñez, almost exactly along the border between Chile and Argentina, and they also outcrop at the eastern end of the Peninsula Levicán. Their contacts with the nearby Ibáñez Formation tuffs and ignimbrites are not exposed due to masking soil cover and saline or brackish lake deposits. However, they contain rafted blocks of blue tuffs and tuffaceous sandstones similar to the adjacent rocks of the Peninsula Ibáñez and are probably a thick subvolcanic rhyolitic dike or elongate dome or dome root intruding part of the Ibáñez Formation. In hand specimen they are weathered brown or pink flowbanded rhyolitic lavas, with some brecciated patches and common calcite and quartz veins. In some places they are also spherulitic, and have drusy quartz and agate amygdules in vugs and cavities.

3.2.3 Basaltic and Andesitic Extrusive Rocks

Extrusive basaltic and andesitic rocks form a minor part of the Ibáñez Formation. They occur as breccias, lapilli tuffs and blocky aa lavas, exposed west of El Maitén, Estero Largo, lower Estero Lechoso, Cerro Bandera Oeste, southwest of Cerro Cabeza Blanca, west of Puerto Rey and southwest of Cerro Pirámide (Fig.3.21). It is notable that several of these lavas occur stratigraphically above a weathered erosion surface in the upper Ibáñez Formation. Depressions in the erosion surface are infilled by stacks of aa lavas (as at El Maitén) or by a single massive blocky lava (at Cerro Cabeza Blanca), overlain by Upper Jurassic rhyolitic coulée flows. Only the outcrops at El Maitén and Cerro Cabeza Blanca are discussed, because they are both well exposed and are among the least altered by subsequent weathering and metamorphic overprints from the Cerro Pirámide intrusions and other more minor intrusive bodies. These have significantly altered the andesitic and basaltic rocks at Estero Lechoso and Cerro Pirámide.

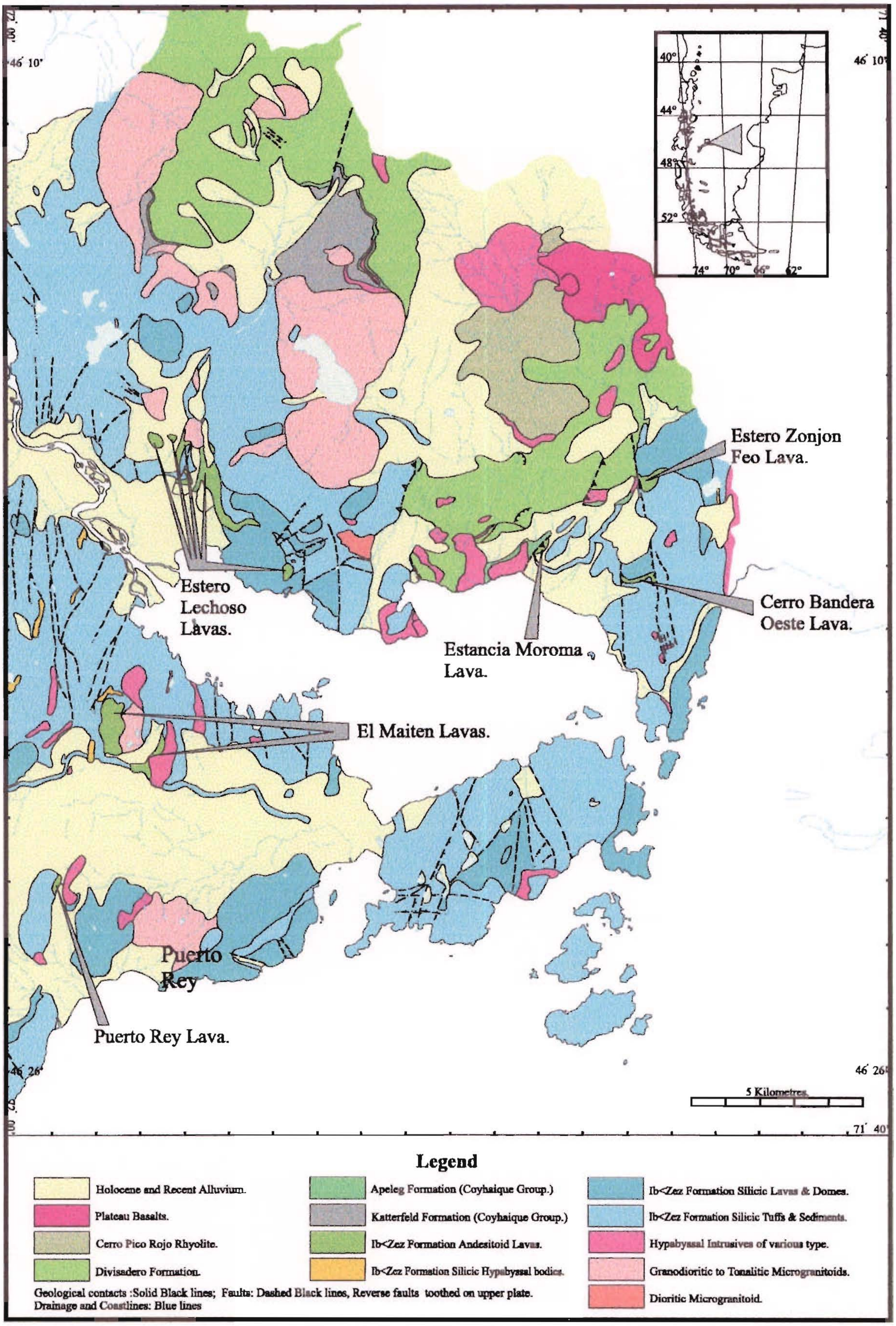


Figure 3.21: Location map showing basaltic and andesitic lavas and associated rocks of the Ibáñez Formation.

El Maitén Basaltic and Basaltic Andesite Lavas

Basaltic to basaltic-andesite lavas cap the top of the hill at GR 272400 4864150, to the west of El Maiten, and make up the bulk of the western face of the hill. They are also exposed to the southeast of the same hill near Estero Largo, in both cases as a stack of aa lavas, with coherent cores of slightly oxidised grey to black basaltic rock, within a carapace of coarsely stratified clast supported breccias. The breccias are made up of angular lapilli through to large block size fragments, and commonly have secondary calcite as a void filling cement. At least three flows are well exposed in the hill at El Maitén (Location WI 84), with each flow having baked the upper rubble surface of the preceding flow and intervening paleosols to a brick red. Each flow may vary in thickness by up to 10m (Fig. 3.22).

On the north and northwest part of the hill west of El Maitén the lavas discordantly overlie red and brown weathered and oxidised volcaniclastic Ibáñez Formation fluviatile sediments, composed of poorly bedded, moderately sorted and poorly rounded coarse sand and fine to medium gravel clasts of blue, green and purple altered tuffs and andesite; poor trough crossbedding and some scour and fill structures are evident. On the east side of the hill are weathered dark brown and purple tuffs and poorly sorted block and cobble matrix supported volcaniclastic debris flows, which overlie the fluviatile sediments. These are in turn unconformably overlain by the lavas. However, towards the south in exposures in the stream canyon cut by Estero Largo, blocky and columnar jointed basaltic andesitic lavas can be seen overlying thick mauve and purple weathered tuffs of the Ibáñez Formation, up to 10m thick (Fig. 3.23). The outcrop relationships show that the base of the lavas is at least locally unconformable on Ibáñez Formation tuffs and volcaniclastic sediments, with the unconformity and high degree of weathering below the lavas implying a significant erosional hiatus. This unconformable relationship within the Ibáñez Formation between andesitic rocks and silicic Ibáñez Formation tuffs and volcaniclastic sediments is best illustrated in a photograph of the hill at El Maitén from the north, in which the andesitic lavas can be seen to be filling in the eastern side of a valley eroded into Ibáñez Formation

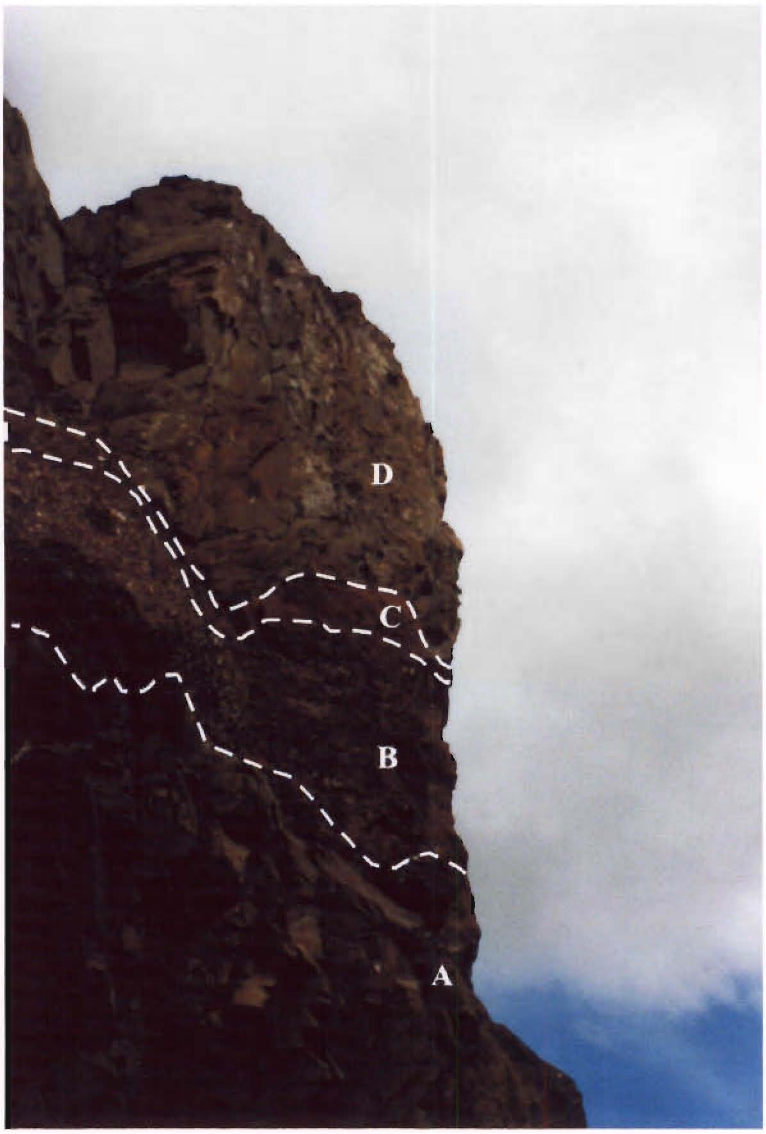


Figure 3.22: Two basaltic lava flows at El Maitén, showing Lava (A), with accompanying flowtop breccia carapace (B) and an intervening baked red paleosol (C) in turn ovelain by the base of a second lava (D). GR 272060 4864280, looking southwest.

tuffs and volcaniclastic sediments (Fig. 3.24).

Southwest Cerro Cabeza Blanca and Cerro Bandera Oeste

On the Peninsula Ibáñez, andesitic lavas occur southwest of Cerro Cabeza Blanca, beneath the precursor tuffs and surge deposits of the overlying rhyolitic dome, and also at Cerro Bandera Oeste, again beneath a coulée lava associated with Cerro Cabeza Blanca.

The lava southwest of Cerro Cabeza Blanca is a single massive blocky lava, probably more than fifteen metres thick (Fig. 3.17). The outcrop was initially mapped as a sill. However, where Arroyo Zanjón Feo cuts through it (GR 287200 4871500), the base and top of this unit are exposed and show brecciated margins, a factor more consistent with its being a lava flow. Autobreccias also occur within the flow. The rock is dark grey to black in colour, aphanitic or slightly porphyritic with plagioclase phenocrysts up to 3mm. Once again, as at El Maitén, the andesitic lava overlies purple and mauve clayey and weathered tuffs of the Ibáñez Formation, but is overlain by rhyolitic tuffs and surge deposits associated with Cerro Cabeza Blanca.

Two kilometres to the south, west of the fault passing immediately to the east of Cerro Bandera Oeste at GR 287770 4869250, the andesitic rocks outcrop on the south side of Cerro Bandera Oeste, below the rhyolite coulée lava and the associated rhyolitic breccias and tuffs are less well exposed. This andesite is <10 m thick, but again overlies weathered mauve Ibáñez tuffs. The double cliffline of the outcrop suggests two flows, but no intervening breccias are exposed (see Fig 3.20). In hand specimen the andesite is highly vesicular and altered, with a mauve or grey aphanitic groundmass. Plagioclase phenocrysts are altered and secondary chlorite and white agate or zeolite material commonly line the elongate flow-orientated vesicles. Although the top and base are not well exposed, and thus no flow top and base breccias, the occurrence above weathered Ibáñez Formation Tuffs and below a rhyolitic lava from Cerro Cabeza Blanca is very similar to that of other basaltic and andesitic lavas mapped in the area and thus this outcrop is included as a lava flow rather than a sill.

Figure 3.23: Basaltic lavas in the canyon of Estero Largo, overlying weathered and eroded purple tuffs and ignimbrites. GR 273040 4862440, looking south.

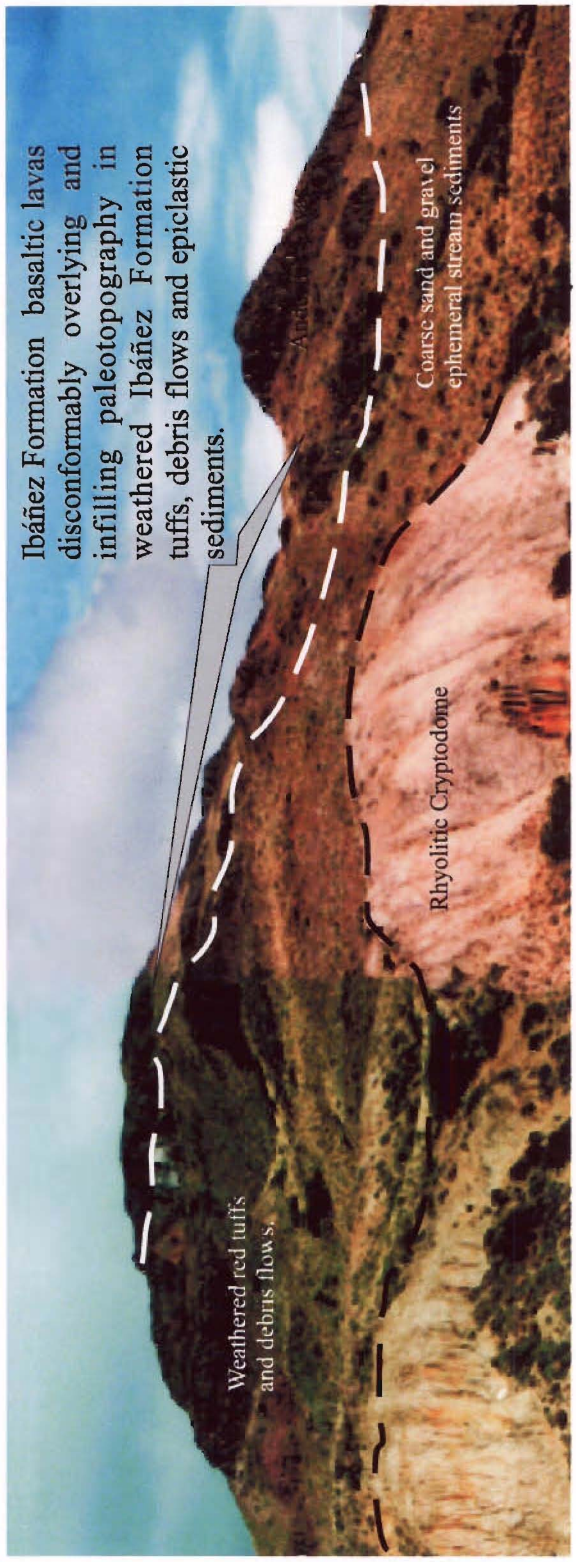


Figure 3.24: Photomosaic of El Maitén from the north showing the basaltic lavas which cap the hill, lying unconformably on weathered and eroded tuffs (White dashed line indicates erosion surface on which the lavas were erupted). GR 272130 4864760, looking south.

A small remnant of an andesitic lava breccia, underlain by breccia and bedded block and ash tuffs outcrops slightly southwest of Estancia Moroma at GR 284500 4869300, and is faulted against the Apeleg Formation of the Coyhaique group. This outcrop is only 50m across, but like the other andesitic rocks in the Cerro Cabeza Blanca area, it disconformably overlies distinctively weathered Ibáñez Formation tuffs.

3.2.4 Volcaniclastic Sediments and Non Volcanic Rocks

Tuffaceous sandstones are intercalated with tuffs and ignimbrites throughout the Ibáñez Quadrangle, but the best exposures of Ibáñez Formation epiclastic sediments are in the western side of the area, around El Maitén, El Maitenal and the Rio Ibáñez (Fig. 3.25). Their depositional environments vary widely, and may include: fluvial gravels, sheetflow flood and overbank deposits, deltaic sequences, debris flows, lacustrine siltstones and shales. Fossil fern fronds, wood fragments and trace fossils are occasionally present. In the West Ibáñez to Puerto Ibáñez areas, the occurrence of fining upwards deltaic sequences indicates the presence of fluvial environments draining into standing water, and with the occurrence of debris flows, peperitic intrusives, thick ponded ignimbrites, lithic tuffs, lag breccias and rhyolite domes this may indicate a caldera deposition setting, although no structural expression of any ancient caldera was found due to pervasive faulting of the sequence. The Peninsula Ibáñez and Peninsula Levicán areas, conversely, show thinner tuffs and ignimbrites intercalated with fluvial channel sandstones, sheetflow flood and overbank sandstones, together with occasional andesitic lava flows and dacite to rhyolite domes, perhaps indicating more distal ignimbrite outflow sheet depositional environments.

Deltaic, Lacustrine and Fluvial Deposits

Fluvial gravels are found on the Peninsula Levicán, and west of El Maitén and Arroyo Zanjón Feo. The two latter occurrences appear to be above the erosion surface cut into older Ibáñez Formation tuffs.

The gravel deposits on the Peninsula Levicán (GR 282300 4862000) are a small fault

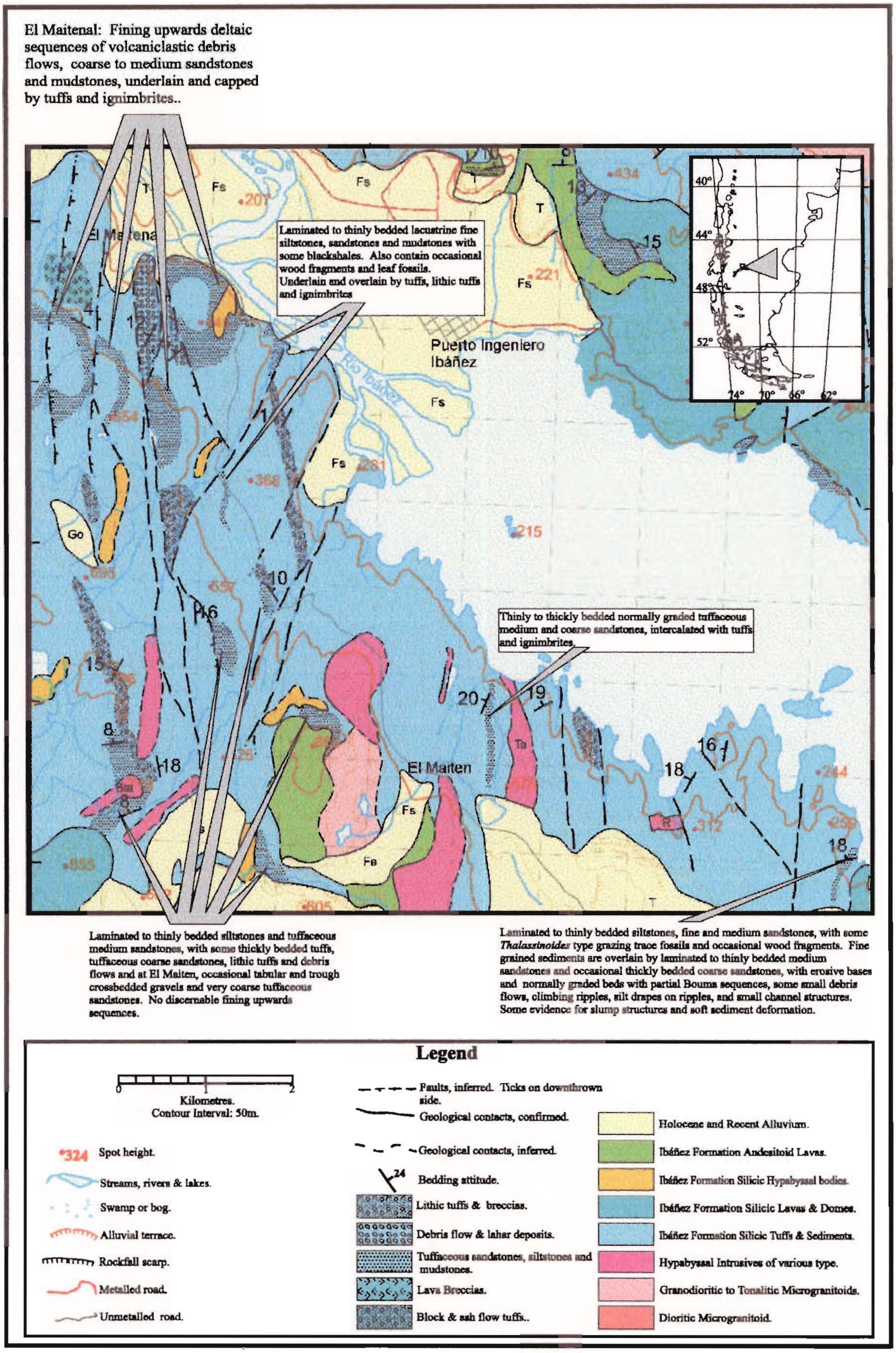


Figure 3.25: Location map showing outcrop areas for epiclastic sediments in the western portion of the Ibáñez Quadrangle.

bounded fragment, steeply dipping to the east and overlain by lithic rich tuffs. The gravels are thinly to thickly bedded and poorly sorted, with blue or brown clasts in a sparse coarse sandy matrix. Thinner beds of normally graded pebbles and gravels are intercalated with thickly bedded debris flow or mass flow deposits that are normally graded from boulder and cobble sizes at their base through to gravels and coarse sands at their tops. Some low angle crossbedding and chute and pool structures occur in the pebbly and sandy deposits. Clasts are sub-angular to poorly rounded fragments of tuff and silicic volcanics, weathered brown or light blue, particularly in the graded gravel beds. These rocks show a poor fining upwards sequence over about 20m of thickness, and may be part of an alluvial fan or scree system.

West of El Maitén, on the north side of the hill (GR 272300 4864500) are massively bedded, weathered red and brown, fine to medium gravels and coarse sandstones. They are comprised of angular to poorly rounded clasts with some trough crossbedding. These sediments overlie weathered tuff and ignimbrite, and are intercalated with and overlain to the east by tuffs and debris flow deposits; no grainsize trends are identifiable. The angular clasts, massive bedding, poor trough crossbedding and the association with debris flows indicate that these rocks may be alluvial scree or fan deposits or perhaps braided stream deposits fed by scree or alluvial fans sediment.

At Arroyo Zanjón Feo (GR 287150 4872500), fluvial sediments occur just below the unconformity between the Ibáñez and Divisadero Formations. Dark mauve to grey, thinly bedded, moderately sorted pebble gravels with a coarse sandy matrix display graded bedding, both normal and reverse, in some beds and include occasional lenses or wedges of siltstone. Crossbedding indicates paleocurrents flowed to the south. Mudstone ripup clasts, some possible dropstones (Presumably from floating vegetation/treetrunks with stones and soil attached) and silt drapes lie on some crossbedding surfaces.

Lacustrine mudstones occur north of El Maitén (GR 271300 4867000 and GR 271830 4868850) and on the eastern bank of the Rio Ibáñez (GR 271050 4873000). In both these locations, laminated silty mudstones, and cherty blackshales occur beneath finely bedded and laminated sandstones and silts with wood fragments. These finer grained sediments at El Maitén are underlain by tuffs and lithic tuffs, and overlain by lithic tuffs and debris flows, whereas at the Rio Ibáñez, they are overlain by thick ponded ignimbrites.

Fining upwards sequences that may be deltaic and small floodplain deposits are most readily identifiable near El Maitenal, and also slightly further west. At El Maitenal (GR 271100 4869500), thickly bedded tuffs are overlain by thickly bedded polymict debris flows (see below) The debris flows fine upwards into massively bedded normally graded coarse and medium sandstones, with erosive bases, scour structures and partial bouma sequences, suggesting that these sandstones may be lacustrine turbidites. They in turn grade into laminated and occasionally crossbedded thinly bedded volcaniclastic sandstones and some silts, shales and fine sandstones. Mudcrack dessication features and wood fragments lie along soles of some silt and shale beds. Flute and drag marks and rare crossbedding show paleocurrents in SE and NW directions. The occurrence of dessication cracks in the finer grained material at the top of the sequence indicates subaerial exposure, perhaps due to deposition on a lacustrine delta top/floodplain. The top of this sequence is overlain by thick (2–5m) tuffs.

Debris Flow Deposits

Delta front debris flow or possible lahar deposits also occur near El Maitenal at GR 270300 4869000 and GR 271500 4869000 (Fig. 3.26), where massively bedded, poorly stratified deposits with rounded cobbles and boulders in a coarse, pebbly volcaniclastic sandstone matrix. In the latter occurrence, the debris flows have erosive bases on the underlying tuffs, dip shallowly to the northwest and grade upwards into laminated to thinly bedded sandy turbidites as in the fining upwards deltaic sequences described above. Other debris flow deposits associated with fining upwards sandstone sequences are present further west and also on the north side of the hill west of El Maitén.

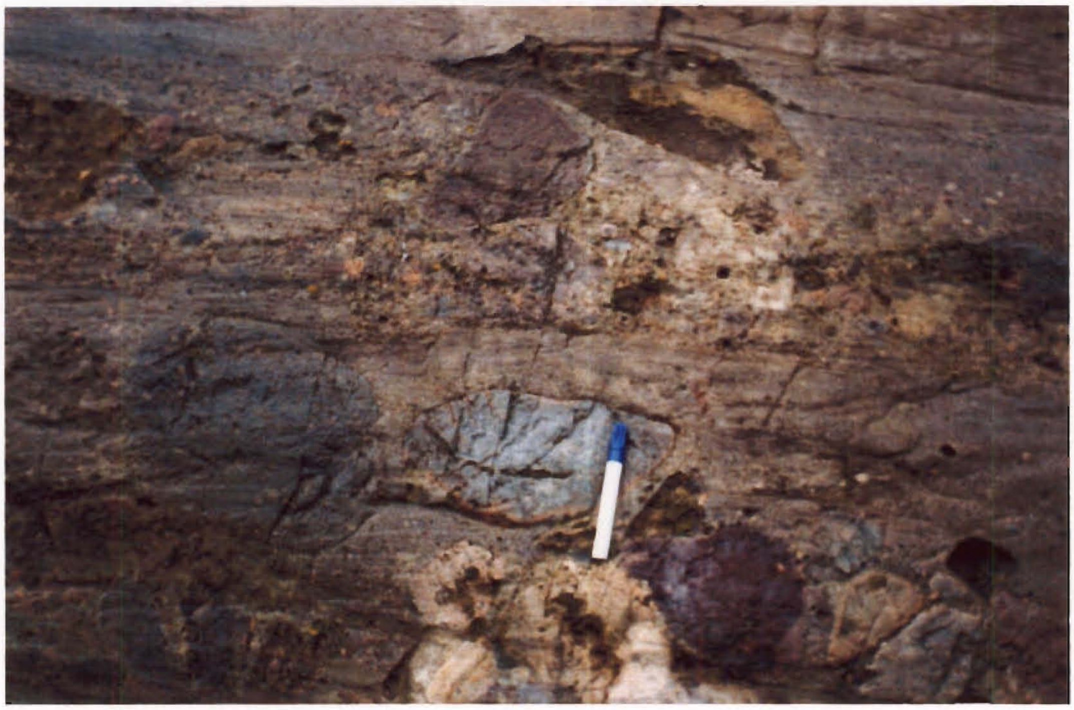


Figure 3.26: Massively bedded matrix supported debris flow with rounded cobbles and boulders of rhyolite, andesite and tuff, in a coarse sandy matrix. GR 271500 4869000, looking west. Pen is 15cm high.

3.2.5 Fossils and trace fossils

A poorly preserved *Ophiomorpha* tube trace fossil was found in massive coarse tuffaceous sandstones beneath the ponded ignimbrites on the east bank of the Rio Ibáñez at GR 271625 4871575. *Thalassinoides* grazing traces/burrows occur in volcaniclastic siltstones and mudstones on the shore of the Bahia Ibáñez three kilometres northwest of Puerto Rey at GR 278700 4862900 (Fig. 3.27. see also Fig. 3.25), associated with wandering traces and wood fragments. Wood fragments occur further up the same shore southwest of El Maitenal (GR 271830 4868850). Plant fossils apart from wood fragments are sparse, but fern leaves were found in laminated tuffaceous sandstones and mudstones with minor blackshales on Peninsula Levicán at GR 282080 4858590.

Figure 3.27: *Thalassinoides* in silty fine sandstones associated with turbidite sandstone sequence at GR 278700 4862900 on the shore of the Bahia Ibáñez.

3.2.6 Alteration, Mineralisation and Low Grade Metamorphism

Diagenetic Alteration

Extensive diagenetic alteration of Ibáñez Formation rocks and their constituent minerals is common, especially to tuffs and basaltic rocks. Most rocks are well lithified, although finer grained tuffs and sediments are often harder than coarser grained material, and some of the occasional fluviatile gravels are quite friable, particularly if much clay is present. Feldspar crystals in Ibáñez Formation rocks are often stained green or pink, and may be altered to swelling clay pseudomorphs. Mafic minerals such as pyroxene, amphiboles and biotite are commonly replaced by chlorite, goethite and hematite. Both the basaltic to andesitic lavas and rhyolitic rocks show some degree of this propylitic style of alteration. In the basic rocks, fractures and vesicles are often filled with calcite, agate, chlorite, clay or zeolites, whereas in the acidic rocks, particularly tuffs, glassy or ashy material is always devitrified, usually to very fine grained siliceous material, presumably comprised of quartz, feldspars and probable zeolites, although also often to clay (see also chapter

4). Calcite is common as a cement or void filling in many tuffs, breccias and epiclastic sediments. In most tuffs, pumice fiamme have been altered to fine white or green clay and occasionally fine muscovite mica (determined upon petrographic examination and XRD). Alteration is more extensive in strongly fractured rocks, and alteration 'haloes', probably related to fluid transmission, can be traced along fracture systems in many outcrops. Also, the upper contact of the Ibáñez Formation, where exposed, shows evidence of a deep weathering horizon with alteration of tuff and lava to soft red and brown clay to a depth of 3-4m. Much of the diagenetic alteration of the lower Ibáñez Formation may be ascribed to varying degrees of burial metamorphism, given that combined thicknesses of up to 2000m of Ibáñez Formation, Coyhaique Group and Divisadero Formation rocks have accumulated in parts of the Aysén Basin. Additionally, hydrothermal activity from coeval and later volcanic activity may also be involved in much of the weathering and alteration observed.

Contact Metamorphic Aureoles and Mineralisation

Contact aureoles around minor intrusive rocks are mainly narrow, of the order of a few cm or m, up to 100m about the larger granitoids. Metamorphism in these aureoles may reach the albite-epidote hornfels facies, and occasionally up to the hornblende hornfels facies, with rocks commonly showing epidote as a vein mineral or as disseminated porphyroblasts, and rarely hornblende, biotite and andalusite. Secondary pyrite, tourmaline and chlorite occur as alteration or incipient metamorphic minerals, and prehnite/pumpellyite occurs as very low grade product in veins. Quartz veins of presumed geothermal origin are common throughout the altered parts of the Ibáñez Formation, as are veins of calcite, and occasional barytes. While most quartz veins are barren, there are occasional occurences of sub economic Cu/Pb/Zn deposits of sulphide mineralisation and also disseminated sulphides in tuffs and rhyolites. These occur within the contact aureole of the Cerro Pirámide intrusive, and also as pods and quartz veins with galena, pyrite, covellite and chalcopyrite in silicified Ibáñez Formation andesites and rhyolites below Cerro Farellón's southwest peak. Gossans with goethite, covellite and sphalerite are found associated with the andesites and minor intrusive rocks west of El Maitén.

3.2.7 Structural Geology

The structural geology of the Ibáñez Formation is dominated by small normal faults aligned N-S in the west of the area, but less well aligned in the east. Displacements are either a few metres, or great enough that correlation of individual units cannot be made across the faults. In the Rio Ibáñez valley, towards the upper northwest part of the field area, many of the small faults change their trend to the northwest, matching a northwest-trending lineament visible on a satellite photo as far as the Cerro Castillo area (see 1.4). Some minor reverse faulting occurs, and several of the normal faults have a significant oblique component. At Arroyo Zanjón Feo, there is displacement of a coulée lava flow west of Cerro Cabeza Blanca by 2km south of the probable source dome, and a downthrow of approximately 250m. Fault gouges may have both subvertical and subhorizontal striations and slickensides, indicating both vertical and strike-slip/oblique movements have taken place. Most of the faults present in the Ibáñez Formation do not deform the overlying rocks, except for large reverse faults at Rincón los Arroyos, Estancia Moroma, and perhaps at Arroyo Zanjón Feo, which may be old normal faults reactivated by later compressive textonics. Folding is rare, the only examples being a small rollover anticline against a normal fault on the road into Puerto Ibáñez, and a small, fractured anticline above the minor intrusives east of Arroyo Huemule. The fact that many of the smaller faults within the Ibáñez Formation do not deform the overlying Cretaceous cover rocks indicates that the tectonism responsible for these faults was either coeval with the Ibáñez Formation volcanism/sedimentation, or occurred shortly after Ibáñez times, perhaps during the opening of the Austral Basin, but before deposition of the bulk of the Coyhaique Group and Divisadero Formation.

There is also evidence of intra-formational unconformities/discontinuities. These occur between both silicic rocks (west of the Rio Ibáñez) and between silicic rocks and andesitic rocks (El Maitén, west bank of the Rio Ibáñez above the road to Lago Lapparent, and at Arroyo Zanjón Feo, Peninsula Ibáñez). These features suggest significant hiatuses in volcanic activity during Ibáñez times, with weathering and erosion of older material, followed by eruption of new pyroclastic rocks and lavas, both andesitic and silicic, on top of the older weathered tuffs.

3.3 Coyhaique Group

The Coyhaique Group, defined by Suárez and de la Cruz (1994a), unconformably overlies the Ibáñez Formation and is a transgressive-regressive sequence of shallow marine rocks forming the Aysén Basin expression of latest Jurassic to lower Cretaceous sedimentation in the Austral Basin (Riccardi, 1988). This group consists of three formations. The first is of discontinuous limestones, tuffs and fossiliferous sandstones (Toqui Formation), interpreted by previous workers as high energy deposits from shallow water environments near an active andesitic arc. The Toqui Formation is overlain conformably by a thick (up to 600m) extensive unit of fossiliferous black shales (Katterfeld Formation) associated with anoxic, sheltered marine embayment conditions in Valanginian to Hauterivian times. The Katterfeld Formation grades abruptly into the Apeleg Formation, a homogenous unit of ripple and trough cross bedded sub-tidal and locally deltaic shallow marine sandstones (Ramos, 1981; Bell et al., 1994; Suárez and de la Cruz, 1993).

3.3.1 Toqui Formation

The Toqui Formation (Often regarded as cognate with the Tres Lagunas and Cotidiano Formations, Suárez and de la Cruz (1994b)) was not present within the area mapped, and thus may only be described from examples outside the field area, at the Toqui Mine (GR 267700 5007600) and at Foitzick, (GR 259362 4940385) near Coyhaique.

At the Mina Toqui, the Toqui formation consists of three thickly bedded fossiliferous sandstones bearing ostrea spp, intercalated with tuffs, tuffaceous sandstones and breccias, indicating marine sedimentation in a nearshore environment with active volcanism. The first of the fossiliferous sandstone unconformably overlies the Ibáñez Formation, and is locally metamorphosed and mineralised as a skarn deposit bearing sphalerite, pyrrhotite, chalcopyrite and other sulphides, with the mineralisation associated with a Miocene rhyolitic intrusion (Carríc, 1997).

Conversely, at the Foitzick outcrop, the Toqui Formation occurs above a brecciated dacitic lava of the Ibáñez Formation, as a thickly bedded bioclastic limestone with many finely broken ostrea, echinoid shell and echinoid spine fragments, and without the tuffaceous sediments present at the Mina Toqui, indicating a slightly more distal sedimentation setting to any active volcanism, although still a shallow, high energy environment.

3.3.2 Katterfeld Formation

In the Ibáñez Quadrangle, black shales of the Katterfeld Formation rest on the Ibáñez Formation and outcrop over a large area in the catchment of the Estero Lechoso between Cerro Farellón and Cerro Pirámide, reaching a thickness of 500m. The contact with the Ibáñez Formation is not exposed, but the laminated fine carbonaceous mudstones and siltstones of the Katterfeld Formation occur very closely above weathered red, clayey Ibáñez Formation tuffs and tuffaceous sandstones in Estero Lechoso at GR 276500 4876700, so the contact is almost certainly an unconformity. This interpretation is supported by the very pervasive faulting in the Ibáñez Formation throughout the area that does not effect the Coyhaique Group. Both the Ibáñez Formation and Coyhaique Group near the inferred unconformity are disrupted and cut by sills, small stocks, and dikes of hypabyssal granodioritic to tonalitic rocks associated with the Cerro Pirámide intrusion. Further to the east at Cerro Cabeza Blanca, the Katterfeld Formation is present only as fragments within the marginal zones of hypabyssal intrusives cutting the Apeleg Formation, which in turn can be seen to unconformably overlie the Ibáñez Formation in Arroyo Zanjón Feo (see Fig. 3.28).

The most interesting use of the Katterfeld Formation in the Ibáñez area is in providing paleontological age control, and in illustrating, from the thickness variations, the

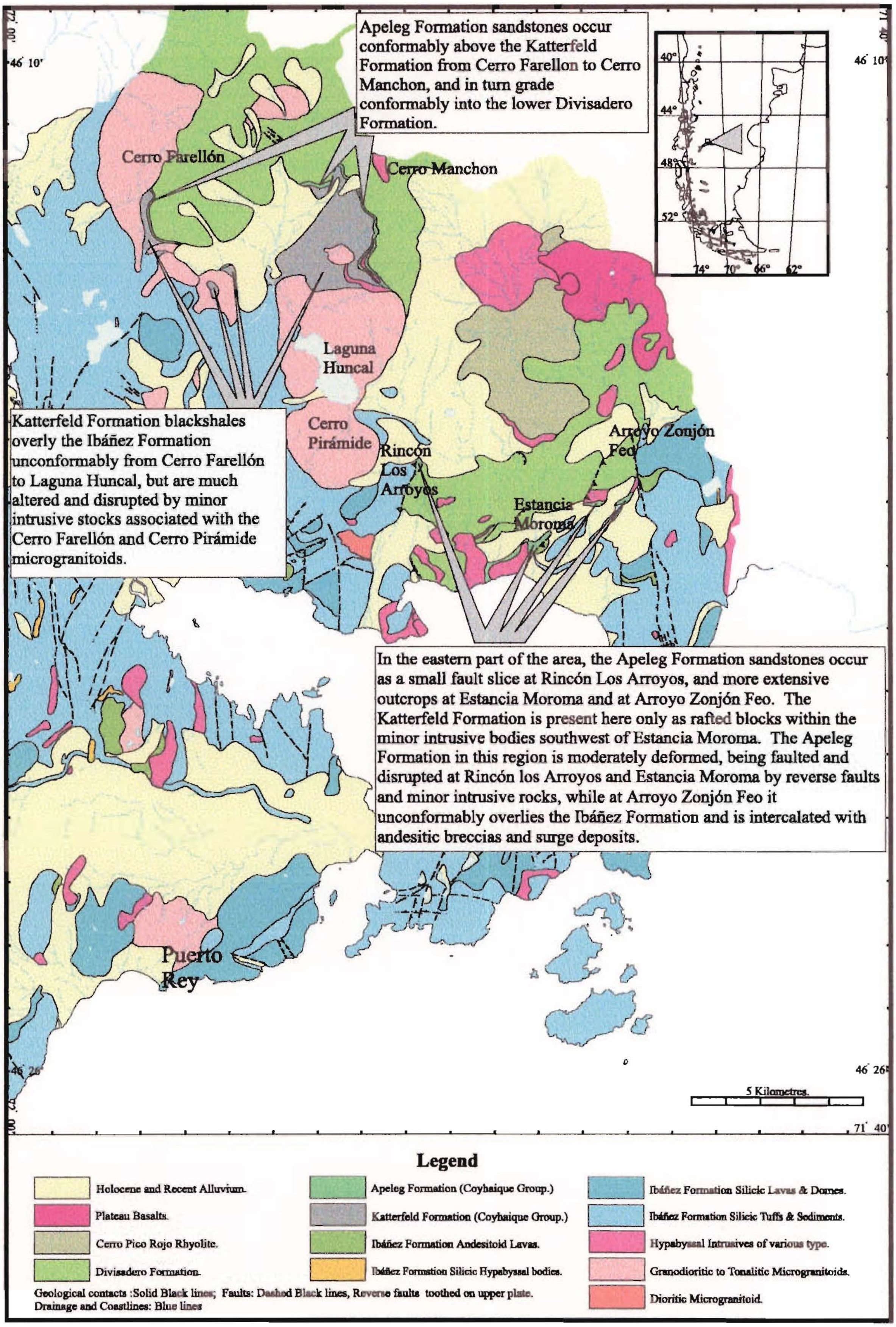


Figure 3.28: Location map for Coyhaique Group units within the Ibáñez Quadrangle.

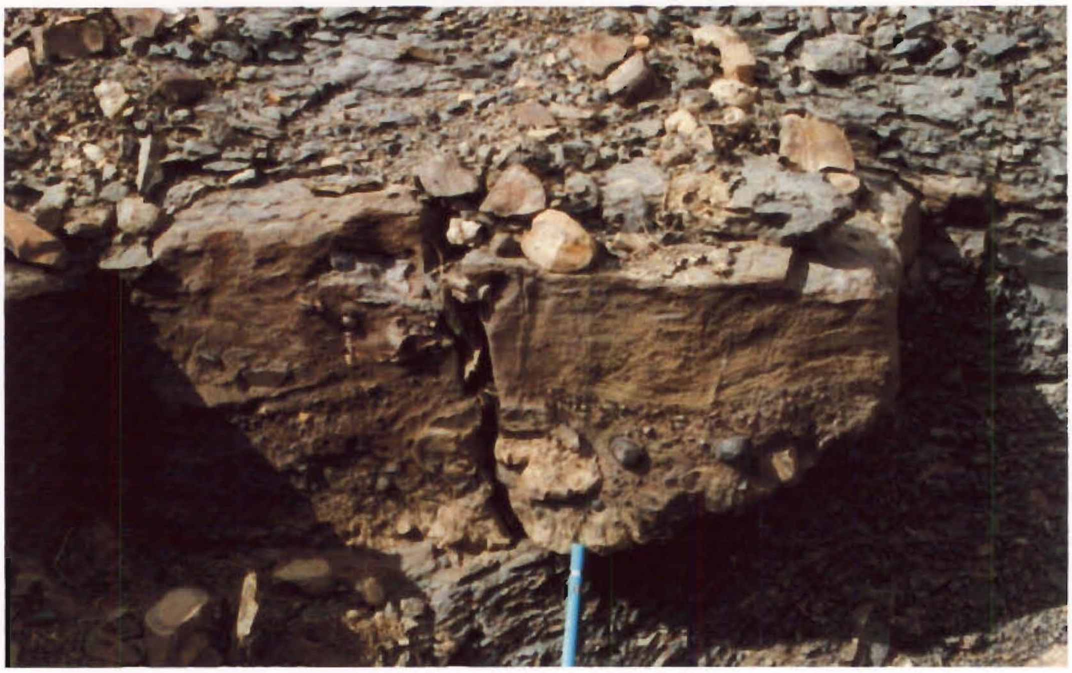


Figure 3.29: Fossiliferous hardground showing small channel structure of calcite cemented sandstone and pebble conglomerate within carbonaceous mudstones of the Katterfeld Formation. GR 278319 4878264.

significant relief cut into the upper Ibáñez surface during the lower Cretaceous. The great variation in thickness of the Katterfeld Formation in the Puerto Ibáñez Quadrangle is important, and supports the possibility of very significant paleotopography in the old Ibáñez surface that was infilled by Coyhaique group and later Divisadero Formation rocks.

The Katterfeld Formation is fossiliferous, with ammonoid, oyster shell fragments, inoceramid bivalves, saurian bone fragments and shark teeth present at GR 278567 4878395 within the major landslide below Cerro Manchón. The ammonoid groups are found associated with small limestone hardgrounds or turbidity-flow related limy sandstones within the shale (Fig. 3.29). Three groups are present, which have been identified as *Crioceratites nolani, Crioceratites duvali* and *Aegocrioceras* (Aguirre-Urreta (1998 b)). *Aegocrioceras* was previously known only from Europe, from the Speeton Clay in the UK and from Germany. (see also Chapter 6, with reference to stratigraphic correlation of this fauna with coeval faunas in the Nuequen Basin).

At Cerro Manchón the Katterfeld Formation is overlain conformably by the Apeleg

Formation. Despite disturbance by an alkaline intrusive sill which exploits the contact between the two, in the upper 20 metres of the Katterfeld formation, isolated ripples of quartzofeldspathic and volcaniclastic sandstone appear, and this clastic sandy sediment proportion within the blackshales can be seen to increase gradually upwards until the shales become a minor component and the sandstones change from small migrating ripples to crossbedded dunes and finally to the massive foreset crossbedded sandstones of the Apeleg Formation. While much of the Katterfeld formation comprises fine grained pelagic sedimentation, the occasional fossiliferous hardgrounds, limy sandstones (sometimes channellised) and the sparse sandy beds in the upper parts of the unit are taken to represent distal examples of turbidity current or similar debris flow sedimentation from either the basin margins or from topographic highs within the basin.

3.3.3 Apeleg Formation

Marine sandstones of the Apeleg Formation are present at Estancia Moroma, upstream of the road bridge over Arroyo Zanjón Feo, on the the western face of Cerro Farellón, and as an arc of outcrops from the south west of Cerro Farellón, up towards Cerro Manchón, then across to the northern extension of the Cerro Pirámide intrusion. A small outcrop is also present as a small fault slice at Rincón Los Arroyos Reverse Fault (see Fig. 3.28). As with the Katterfeld Formation, this unit is important as a marker horizon between the Ibáñez and Divisadero Formations, but in the Ibáñez Quadrangle it is absent at the contact between them in the Arroyo Zanjón Feo immediately west of Cerro Cabeza Blanca. The Apeleg Formation consists of both tidal and deltaic facies, and sometimes grades upwards into continental redbeds of the Divisadero Formation, with channels and algal limestone fragments.

At Cerro Manchón, the sandstones are 100 to 120m thick, with individual beds up to three metres thick, dominated by coarse and very coarse sands and fine gravels with subsidiary, rippled fine sands and some shales and mudstones. Ripup clasts of mudstone are present in albite-epidote facies examples of the Apeleg Formation exposed in the southwest slopes of Cerro Farellon (GR 272995 4878050). The Apeleg Formation at Cerro Manchón is in gradational contact with both the underlying Katterfeld Formation blackshales, and with the overlying basal redbeds of the Divisadero Formation. Within the Apeleg Formation, there are two fining upwards sequences present (see Cerro Manchón measured section, Appendix F). The lower sequence is dominated by thickly bedded, fine, well sorted, rounded conglomerates to very coarse and coarse, moderately sorted, well rounded sandstones with massive foreset crossbedding, and some herringbone tidal crossbedding. The upper sequence, while beginning with similar conglomerate to sandstone bedforms and grainsizes, grades upwards into tabular and trough crossbedded sandstones, with cobble and boulder size dropstones, presumably from floating vegetation or stumps, and carbonised or silicified log sections(Fig. 3.30). There is a lateral gradation of these sandstones into muddy sandstone and siltstone redbeds which form the lower parts of the Divisadero Formation . The upper parts of the Apeleg Formation and lower parts of the Divisadero Formation redbeds both have carbonised and petrified tree trunks, but not in life position, and channel style sandstone deposits, indicating a deltaic to floodplain environment. The lower part of the Apeleg Formation, with foreset and herringbone crossbedding, massive, coarse bedforms and sediments may be more of a delta front to tidal shelf environment. The upper part of the Apeleg Formation is intercalated with lower Divisadero Formation redbeds at Cerro Manchón and Cerro Farellón. Further east at Estancia Moroma it is intercalated with and overlain by andesitic volcaniclastic rocks and surge deposits. In the same area, the Apeleg Formation has both deltaic and tidal sandstone bed forms, and displays an onlap relationship to Ibáñez Formation paleotopography at Arroyo Zanjón Feo. Unfortunately no body fossils were found to constrain the age of the Apeleg Formation, but *Chondrites* trace fossil ichnofacies were found at Arroyo Zanjón Feo.

Figure 3.30: Tabular and trough crossbedded coarse sandstones and gravels with carbonised log sections, upper Apeleg Formation sandstones, Cerro Manchón. GR 279098 4879268.

3.3.4 Alteration and low grade metamorphism

Both the Katterfeld and Apeleg Formations have been folded and thermally metamorphosed by mid to late Cretaceous intrusive rocks (89–101Ma) at Cerro Farellón. Thermal effects have recrystallised the sandstones, up to albite-epidote hornfels facies, for a few tens of metres around the granitoids. The Apeleg Formation is also mildly recrystallised at Estancia Moroma within a few metres of the vent area of overlying/intruding andesitic pyroclastic rocks. In some places slight metamorphism is caused by trachytoid and andesitoid sills; for example, south of Estancia Moroma and directly below Cerro Manchón, the Apeleg Formation shows some quartz overgrowths and development of fine grained epidote and muscovite. Both the Katterfeld and Apeleg Formations show common veining with calcite, occasional anhydrite and the development of calcite cemented concretions, particularly in the Katterfeld Formation.

3.3.5 Structural Geology

Coyhaique Group rocks are reverse and normally faulted near Estancia Moroma, by faults that trend northeast and fade out into the Divisadero Formation, with displacements of approximately 5 m at Estancia Moroma and 15m at Arroyo Zanjón Feo. At GR 284400 4869400, near Estancia Moroma, the Apeleg Formation is locally overturned, and close to the fault is torn apart into a 15–20m wide fault gouge with anastomosing bands of fault pug around lenses or blocks of deformed sandstones and mudstones. At Rincón Los Arroyos, the large reverse fault with its associated synclinal fold includes a fragment of the Apeleg Formation in the fault gouge at an altitude of about 1000m (GR 280800 4871500). The reverse faulting of Ibáñez Formation rocks over Divisadero Formation and Coyhaique group rocks has caused the Divisadero Formation to be folded into a tight syncline to the east of the fault. The Coyhaique group rocks are not exposed in the syncline, but from the included sliver within the fault gouge are inferred to underly the Divisadero Formation. As this formation extends down to the lake level at La Pedregasa (approx. 200m contour) immediately east of the fault, the Coyhaique group may therefore be downthrown to the east by up to 700m, relative to the altitude of the faulted sliver in Rincón los Arroyos. Coyhaique group rocks are also involved in normal faulting and downsag folding related to the stoping structure at Cerro Farellón and deformation associated with the Cerro Pirámide intrusive rocks, mentioned below.

Coyhaique group rocks are thickest beneath Cerro Manchón and Cerro Farellón, whereas further east at Estancia Moroma, the Katterfeld Formation is present as a trace only and the Apeleg Formation is less than 100m thick. At Cerro Cabeza Blanca the Coyhaique group is absent altogether and Divisadero Formation tuffs have been deposited directly unconformably on the Ibáñez Formation. These thickness changes illustrate the irregular nature of the Ibáñez surface they were deposited on, and indicate that some rocks of the Ibáñez Formation were only thinly covered or remained emergent during the deposition of the marine rocks. Alternatively, some areas of the Coyhaique Group rocks were eroded prior to deposition of the Divisadero Formation. From this, it can be seen that the

Coyhaique group cannot be completely relied upon for use as a marker horizon between the Ibáñez and Divisadero Formations, especially near the margins of the Austral basin. The area studied is close to the southeast margin of the basin as determined by modern outcrop relationships.

3.4 Divisadero Formation

The Divisadero Formation is dominated by rhyolitic to dacitic tuffs and tuffaceous sandstones, with occasional rhyolitic ignimbrites. Rhyolitic ignimbrites and tuffs become more common towards the north and west, outside of the area mapped and towards the type sections of the Divisadero Formation at Cerro Divisadero near Coyhaique.

In the Ibáñez Quadrangle the lower parts of the Divisadero Formation consist of continental redbeds with channel structures and fossilised wood, which have a gradational and interdigitating contact with the underlying Apeleg Formation of the Coyhaique Group, as at Cerro Farellón. However, further east at Arroyo Zanjón Feo, the redbeds are entirely absent, and Divisadero Formation tuffs overlie an unconformity surface truncating Ibáñez Formation rocks. Stratigraphic columns were taken of the Divisadero Formation from Cerro Manchón, and also from the type areas further north at Coyhaique, from Cerro Divisadero and Cerro Montreal. Outcrops of the Divisadero Formation at Lago Frio and Lago Castor were also visited (Fig. 3.31. see also measured sections of Cerro Divisadero, Cerro Manchón and Cerro Montreal F).

3.4.1 Pyroclastic Rocks

Compared to the Ibáñez Formation, the Divisadero Formation within the Ibáñez Quadrangle has more airfall tuffs and epiclastic sandstones and fewer rhyolitic ignimbrites/welded tuffs. Much of the stratigraphy is characterised by repeated thin tuffs, tuffaceous sandstones, channel sandstones, and paleosols (especially at the base), interspersed with the occasional thick tuff, and rarely a welded ignimbrite. Tuffs with accretionary lapilli are common, and almost diagnostic of Divisadero Formation in this area. Welded rhyolitic

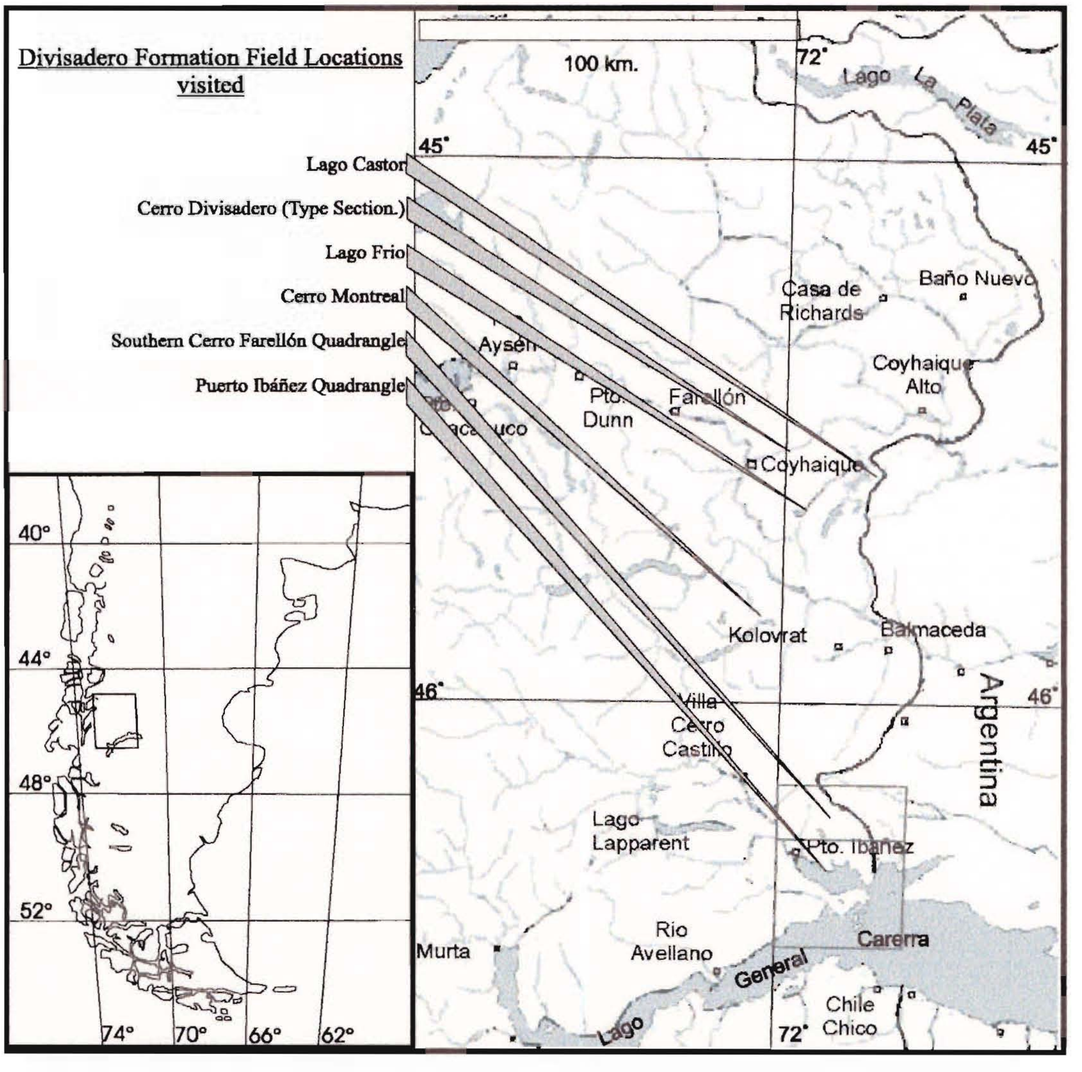


Figure 3.31: Location Map of measured sections and outcrop locations visited within the Divisadero Formation.

ignimbrites are rare in the Puerto Ibáñez Quadrangle, but are common in the type section at Cerro Divisadero and in sections taken at Lago Frio and Lago Castor. The section taken at Cerro Montreal includes massive lag breccias with megablocks up to 10m at the base of some tuffs, unlike the sections measured at Coyhaique and Puerto Ibáñez. The Cerro Montreal section may be the most proximal of Divisadero Formation seen, whereas the Coyhaique (Cerro Divisadero, Lago Frio, Lago Castor) sections are more distal and the Puerto Ibáñez exposures would appear to be the most distal. The Puerto Ibáñez exposures of the Divisadero Formation are dominated more by airfall tuffs and floodplain sediments, whereas the Cerro Montreal section, and to a lesser extent the Coyhaique sections, are a series of repeated large tuffs with minor intercalated airfall and epiclastic sediment. However, there is no evidence that Divisadero Formation tuffs from Puerto Ibáñez and those from the measured sections in the Coyhaique region are sourced from the same eruptive centre(s).

Tuffs and Ignimbrites from the Cerro Manchón section and from Cerro Farellón are generally less than two metres thick; only two units thicker than ten metres were observed in the section at Cerro Manchón. In the type section at Cerro Divisadero, east of Coyhaique, tuffs and ignimbrites are more common than in the Puerto Ibáñez Quadrangle, range up to sixty or seventy metres in thickness, are more laterally continuous and have thicker intercalations of tuffaceous sediments between tuffs than the thick ponded igimbrites of the Ibáñez Formation. Except for the thick proximal tuffs at Cerro Montreal, Divisadero Formation tuffs and ignimbrites are lithic poor. Most are rhyolitic, containing crystal fragments of quartz and sodic plagioclase, and occasional biotite, in an ashy matrix, often welded and with a conchoidal glassy fracture, and white or green altered pumice fiamme, particularly in examples from Cerro Divisadero and Lago Castor. Columnar jointing was not present in most Divisadero Formation ignimbrites from the Ibáñez Quadrangle, but is particularly common in examples from Cerro Divisadero, Lago Castor and Lago Frio, where glassy, welded ignimbrites occur often.

Lapilli tuffs are common and well preserved, as opposed to the Ibáñez Formation, in which such structures are rarely present. Accretionary lapilli from 5mm to 2cm in diameter were observed regularly in airfall tuffs from the Divisadero Formation at Cerro Divisadero and Cerro Manchón, and at Cerro Farellón.

Pinch and swell bedded surge tuffs were noted only from the Cerro Montreal area, where they are interpreted as part of the co-ignimbrite ashfall deposits of the thick, lithic rich ignimbrites that make up the bulk of the Cerro Montreal section.

3.4.2 Andesitic Lavas

One example of an andesitic lava in the Divisadero Formation occurs in the Ibáñez Quadrangle, above Estancia Moroma, about 3 km southeast of Cerro Pico Rojo (GR 286700 4872150). This single outcrop is downthrown approximately 15 metres to the east by the normal fault that cuts the Ibáñez Formation in Arroyo Zanjón Feo, and is a blocky a'a lava flow, about 5m thick, with prominent lava breccias exposed in the faulted area. No andesitic lavas were found at Cerro Divisadero, Cerro Montreal, and Lago Frio, and an andesite occurring at the Lago Castor cross section was discordant, and was interpreted as being a post-Divisadero age dike.

3.4.3 Epiclastic Sediments: Basal Redbeds and Deltaic Horizons

As discussed above, a conformable or paraconformable transition between Apeleg Formation and the lower redbeds of the Divisadero Formation occurs at Cerro Manchón, but northwest of Cerro Cabeza Blanca, the redbeds are absent and Divisadero Formation tuffs rest directly upon weathered Ibáñez Formation rocks, in unconformable contact. This would appear to complement the onlap relationship of the Apeleg Formation to the upper Ibáñez Formation southwest of Cerro Cabeza Blanca. Sparse fossil material consists of carbonised and silicified wood fragments within the lower redbeds at Cerro Manchón and within the lag conglomerates of some channel deposits. Debris flows in the redbeds at the Cerro Manchón section also contain wood fragments and allochthonous chunks of sandstone filled with algal oncolites which have nucleated on wood and perhaps bone fragments.

Channel structures and conglomerates occur, notably in the redbeds at the base of the Formation, but also at higher levels. Fining upwards sequences of tuffaceous sandstones and siltstones with tabular and trough crossbedding, interpreted as channel sandstone deposits, occur between ignimbrites at the Cerro Divisadero, Lago Frio and Cerro Montreal sections, but are subordinate to the thick tuffs which dominate the formation. However, the Cerro Manchón section in the main mapping area is dominated by sequences of reworked tuffaceous material intercalated with primary tuff and ignimbrite deposits.

3.4.4 Alteration and Low Grade Metamorphism

The Divisadero Formation generally shows low levels of alteration, probably only deuteric and burial related diagenetic changes only, as many welded tuffs still show glassy textures in hand specimen, as well as widespread preservation of primary vitroclastic textures (see Chapter 4). Alteration is most obvious in the pink staining of feldspars in many tuffs, as well as the alteration of pumice fiamme to pale green clayey muscovite. However, around the high level granitoids of Cerro Farellón and Cerro Pirámide there are contact metamorphosed rocks up to albite-epidote facies, with consequent destruction of any relict primary textures in pyroclastic rocks and recrystallisation of groundmass ashy material and pumice fiamme. Some minor sulphide mineralisation occurs southwest of Cerro Farellón, either disseminated or in quartz veins.

3.4.5 Structural Geology

Simple folds occur where the Divisadero Formation has been intruded by tonalitic to granodioritic stocks. Horizontal or slightly tilted beds with open, inclined synclinal folds occur adjacent to Cerro Farellón and Cerro Pirámide, with the steeper limb lying towards the intrusive body. The peaks of the Cerro Farellón range are of Divisadero Formation, and some Coyhaique Group, roofing the underlying granitoid, and these rocks have relaxed into into the underlying intrusive rock, with some block faulting and stoping of large fragments. There is also a fault between the Cerro Farellón block and the Cerro Manchón area, where Coyhaique Group and Divisadero rocks are downfaulted to the northwest, with the northwestern rocks forming a "drag" fold with the steeper limb up towards the fault. This also may be due to subsidence into the Cerro Farellón intrusion. A similar "drag" structure occurs on the southwest side of the Cerro Farellón block, also adjacent to disrupted rock intruded by many tonalitic dikes. It may be that the Cerro Farellón area represents an intrusion stoping its way upwards, forming a possible 'suspect' for a caldera (see Fig. 3.33).

Steep reverse faulting occurs east of Cerro Pirámide, at Rinćon los Arroyos, where Ibáñez Formation rocks are faulted up and over Divisadero Formation by some 500m, resulting in a syncline east of the fault where Divisadero rocks closest to the fault form the west limb of an assymetric syncline with a brecciated and sheared-out hinge zone. Reverse faulting also occurs slightly further east at Estancia Moroma, again with shearing of Divisadero and Coyhaique group rocks against Ibáñez Formation rocks which are reverse faulted over them from the east. This fault disappears under moraine and outwash gravels to the northeast.

East of the bridge over the Arroyo Zanjón Feo, an oblique/normal fault that cuts the west side of Cerro Cabeza Blanca also continues upwards into the Divisadero Formation, downthrowing the Divisadero Formation to the west by 15-20m. This fault also displaces the underlying rocks of the Ibáñez Formation to a greater degree, and the displacement peters out upwards into the Divisadero Formation, indicating a probable growth fault associated with the subsidence of the Aysén basin, with movement persisting into Divisadero Formation deposition times.

3.5 Cerro Pico Rojo Rhyolite

These rocks form a peralkaline rhyolite dome complex of fine grained, grey and pink aphanitic rhyolitic lavas and obsidians, often flowbanded, outcropping in the northeast of the Ibáñez Quadrangle and the southern portion of the Farellón Quadrangle. They are erupted through and onto a surface at or near the top of the Divisadero Formation, and retain part of an apron of pumiceous ignimbrites and coulée lava flows (see Fig. 2.5). This complex may postdate the Divisadero Formation, but the nature of its contacts with the Divisadero Formation are difficult to determine as it is hard to find contacts not masked by glacial gravels. The dome rocks are overlain by plateau basalts to the northeast, and are underlain by either the Divisadero Formation or, to the north, a large but poorly exposed basaltic andesite sill or lopolith to the north. To the south the rhyolites are intruded by basaltic sills and dikes. Distinctive red weathering stains have led Cerro Pico Rojo rocks to be mapped as basaltic rocks in previous photogeological interpretations. Pinaccle erosion has formed high spines in the blocky cliffs within the dome. To the western side, the dome still has bands of obsidian, whereas nearer Cerro Pico Rojo itself there are small pumice flows and contorted, complexly folded flowbanded rhyolites. The core of the dome is of spherulitic rhyolite with distinctive weathering features, including tall spines and 'onion skin' layering. Although the northern extent of this complex was mapped mainly by air-photo interpretation, there are small outliers of similar flowbanded peralkaline rhyolitic rocks under the Plateau Basalts on the border with Argentina.

3.6 Post Divisadero Plateau Basalts

The first indication of this formation is a basaltic andesite intrusion, subvolcanic, occurring beneath the plateau basalts, probably as a sill in the top of the Divisadero Formation. Overlying this are lava flow units, almost flat-lying, of thin basaltic lavas in a thick (200m+) stack, infilling depressions in the Cerro Pico Rojo Rhyolite and the Divisadero Formation. This unit was poorly mapped due to time constraints. Lavas are dark grey aphanitic rocks, with pahoehoe flows, 1–5m. thick, with intercalated baked paleosols and basaltic airfall tuffs. Pyroclastic rocks are exposed on the northeastern side of the peralkaline rhyolites, and consist of a dissected spatter cone overlying both the Divisadero Formation and the Cerro Pico Rojo Rhyolite, and are intercalated with and possibly commonly sourced with the nearby pahoehoe lava flows. There are common spatter beds with eutaxitic textures, and ribbon bombs, cowpat bombs and spindle bombs are present. Cavities and vesicles within these rocks contain secondary silica minerals in the form of veins and geodes of pale white agate. This small unit of plateau basalts is probably an equivalent of the Buenos Aires Basalts, from their type locality south of Lago General Carrera at the Meseta Buenos Aires. (Skarmeta (1978)).

3.7 Minor Intrusive Rocks

3.7.1 Minor intrusives within the Ibáñez Formation

The Ibáñez Formation is host to a wide range of minor intrusive rocks. Many subvolcanic sills and irregular bodies of granodioritic composition, mainly associated with the major granitoids, intrude the Ibáñez Formation at Cerro Farellón, Cerro Pirámide, Puerto Ibáñez and El Maitén. Numerous basaltic, andesitic and rhyolitic sills and dikes are found throughout the area, and a minor alkaline assemblage of sills and dikes of trachyte, trachybasalt, trachyandesite, phonolite, and tephritic basalt, mainly occurs on the Peninsula Ibáñez and the Peninsula Levicán.

3.7.2 Minor intrusives within the Coyhaique Group

Apart from the main granitoid intrusions at Cerro Pirámide and Cerro Farellón, the Coyhaique Group is intruded by a small granodiorite stock northeast of Laguna Huncal in the headwaters of Estero Lechoso, associated with Cerro Pirámide, as well as a trachytic sill at Cerro Manchón. Dacitic stocks and dikes, including xenolithic blocks of Katterfeld Formation, cut the Apeleg Formation at Estancia Moroma, and basaltic dikes cutting the Apeleg Formation at Arroyo Zanjón Feo have large amphibolitic xenoliths, perhaps related to an alkaline magma chamber or amphibolitic basement.

3.7.3 Minor intrusives within the Divisadero Formation

The Divisadero Formation is mainly intruded by granodioritic offshoots from the Cerro Farellón intrusives that have a more subvolcanic texture. Towards the east, around Cerro

Pico Rojo, there are basaltic, basaltic andesitic, trachybasaltic and trachyandesitic dikes and sills. In particular, a large basaltic andesite sill or lopolith intrudes the Divisadero Formation north of Cerro Pico Rojo, and a thick basaltic sill can be seen north of Cerro Cabeza Blanca. Basalt dikes are most likely associated with the eruption of the plateau basalts northwest of Cerro Pico Rojo. At Cerro Manchón, a thick basalt dike can be seen to have fed a small lopolith of basalt with an associated basaltic lapilli tuff deposit nearby. The lower Divisadero Formation at Estancia Moroma is intruded by the same complex of dacitic stocks and dikes that intrudes the Coyhaique Group in that location.

3.8 Granitoids and Microgranitoids

High level granitoids and microgranitoids intrude the Ibáñez Formation, Coyhaique Group and Divisadero Formation throughout the central and western parts of the Ibáñez Quadrangle. These rocks are shown in Fig. 3.32.

3.8.1 Cerro Farellón Complex

Several related bodies of granodioritic to granitic composition intrude the Ibáñez Formation, Coyhaique group and Divisadero Formation rocks around the Cerro Farellón massif. The main body of this complex outcrops on the northwest slopes of Cerro Farellón and is a high level granitoid with miarolitic cavities, a thin, but well developed metamorphic aureole, and significant collapse structures of the Divisadero and Coyhaique Group roof rocks into the granitoid (drag folds at margin of descending block and normal faulting within descending block), indicating a high level intrusion that was stoping its way into the Divisadero Formation, and may be a suspect for a caldera structure. Smaller bodies of similar granodioritic composition outcrop to the southwest and northeast of Cerro Farellon, and dikes of granodioritic to microgranodioritic composition are found throughout the Cerro Farellon area, as far southwest as El Progresso. Ibáñez Formation, Coyhaique group and Divisadero Formation wall rocks are metamorphosed up to hornblende facies and albite-epidote facies in places, and parts of the Katterfeld shale have been extensively

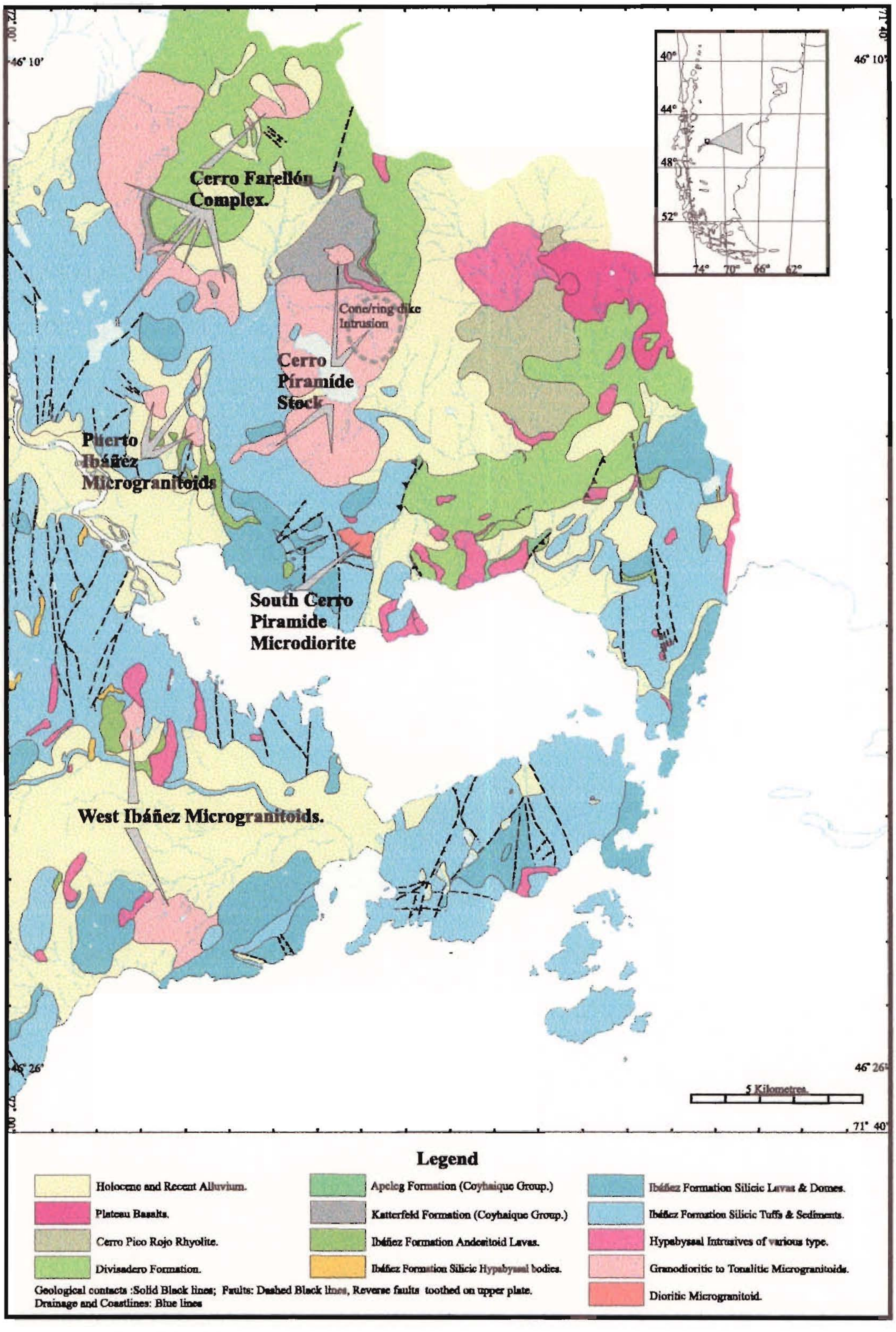


Figure 3.32: Location Map of Grantoid and Microgranitoid intrusive rocks of the Ibáñez Quadrangle.

silicified. Minor mineralisation of the country rock has occurred around this granitoid, with both disseminated and vein sulphide minerals of Pb,Zn,and Cu occurring in trace amounts. These have been mined on a very small scale by local families. The largest exposure of this complex, in the western slopes of Cerro Farellón, has been dated by Ar-Ar methods to 89.3±3.7Ma (see Chapter 6)(Fig. 3.33).

3.8.2 Cerro Pirámide Granitoid/subvolcanic Stock

This intrusion outcrops as a double cored stock forming two prominent peaks, Cerro Pirámide being the most well known, with Laguna Huncal occupying the saddle between it and the cone sheet intrusion that forms the northwest peak to the south of Cerro Manchón. It is a tonalitic to granodioritic rock with quartz, plagioclase and altered hornblende in microgranitic textures at its lower contacts against the Ibáñez Formation, but is petrographically a hypabyssal porphyritic plagioclase-quartz dacite at the peak of Cerro Pirámide. It intrudes the Ibáñez Formation, Coyhaique Group and Divisadero Formation. In particular, to the north of Laguna Huncal the Cerro Pirámide granitoid spalls off a number of small sills into the Coyhaique group, and a small sub-stock intrudes the Katterfeld Formation blackshales. Northeast of Laguna Huncal, the stock intrudes Coyhaique group and Divisadero Formation, and displays a distinctly weathered crater-like structure, reflecting at least one phase of ring or cone sheet emplacement of porphyritic hornblende microgranodiorite after collapse of an initial circular stock back into the magma.(see Fig. 2.3). The collapsed granodiorite block in the centre of the structure is clayey and altered, with replacement of feldspars and mafic minerals by clays and epidote, while the outer ring is of fresher material. Intrusion of the stock has folded the Divisadero Formation immediately to the northeast of this structure. To the west of Cerro Pirámide, the stock includes large blocks of country rock and spalls off several minor sills, dikes and irregular intrusive bodies into the Ibáñez Formation, which have converted the wall rocks to hornfelses of albite-epidote facies.

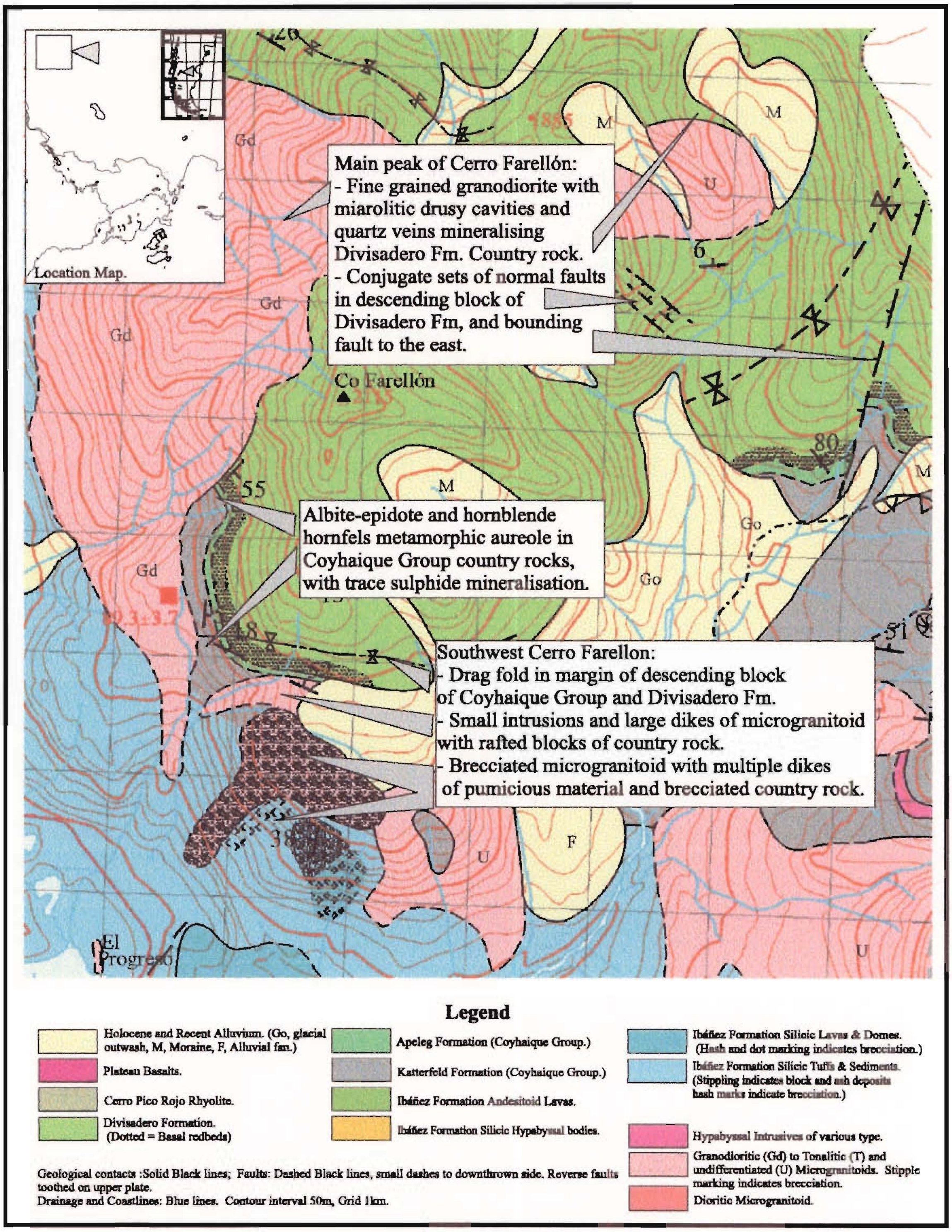


Figure 3.33: Excerpt from main geological map showing features of the Cerro Farellón Complex, including collapse structures of the roof rocks and marginal drag folds.

3.8.3 South Cerro Pirámide Microdiorite

This rock is a small diorite stock intruding the Ibáñez Formation on the south slopes of Cerro Pirámide at GR 279000 4869000. It is cut but not much displaced by some of the minor faults in the Ibáñez Formation in this area. In hand specimen it is quite strongly altered, with common visible pyrite in some samples, and is otherwise a dark grey rock with crystals of plagioclase, hornblende and biotite, up to 3mm in size. It is surrounded by a narrow metamorphic aureole in which the Ibáñez Formation tuffs and sediments are cut by quartz veins with minor sulphide mineralisation and hornfelses of albite-epidote and hornblende facies.

3.8.4 Puerto Ibáñez Road Cutting Microgranitoids

Several small granodioritic to tonalitic granitoid stocks intrude the Ibáñez Formation at three places near the road into Puerto Ibáñez and around the Estero Lechoso, (GR 273300 4872725, 274350 4873950 and 274440 4871950). These rocks are fresh and well exposed at La Masira and in the roadcuts, with well developed albite-epidote facies hornfelse aureoles, and sharp intrusive contacts. The granitoids vary from microgranitic to porphyritic granular dacitic textures, that indicate their subvolcanic nature. The La Masira sample, PI 62, was sampled for Ar-Ar dating (see Chapter 6).

3.8.5 West Ibáñez Microgranitoids

These rocks outcrop at El Maitén and Puerto Rey, (GR 272580 4863880 and 273320 4858150) as irregular granodioritic microgranitic stocks intruding the Ibáñez Formation and surrounded by thin metamorphic aureoles of albite-epidote facies hornfels. At both locations there are minor amounts of sulphide vein mineralisation associated with the intrusions, usually including galena and sphalerite.

Chapter 4

Petrography of the Ibáñez Area

This chapter is a summary of the main petrographic characteristics of each formation discussed in Chapter 3. A total of 470 thin sections were cut, of which approximately 320 are summarised here. Descriptions of the mineralogy and textures of typical examples of each formation are presented, and illustrated with appropriate figures and photomicrographs. Full petrographic descriptions for those samples summarised in the text are presented in Appendix A.

Basement Schists

Petrographic description is limited to those samples from the Bahia Exploradores Road, as most other locations visited were from widely scattered areas which cover a wide range of metamorphic grades, and may include several different terranes. The Bahia Exploradores samples are the closest basement to the main field area at Puerto Ibáñez, although some have been thermally influenced by the North Patagonian Batholith (see Fig. 3.6 after Skarmeta (1978).

4.0.6 Bahia Exploradores Road transect

Six samples were taken adjacent to the batholith, from three locations along the Bahia Exploradores Road, along the Rio Norte, west of Puerto Tranquilo. These rocks are amphibolite facies granitic and amphibolitic gneisses with *lit-par-lit* injection textures, greenschist facies pelitic schist of the chlorite zone, and marble and greenschist facies ankerite zone calc-silicate schist, respectively. The three samples taken closest to the batholith show mineralogy indicating a higher facies and granoblastic textures consistent with strong thermal metamorphism, whereas the schist samples show greenschist facies mineralogy, segregation layering and crenulation cleavage textures consistent with a regional dynamothermal metamorphism. These samples are very similar to those described by Skarmeta (1978) from the Capilla del Marmols and west of Puerto Tranquilo, although the contact with the batholith was found to be slightly further west than that originally mapped along the Rio Norte.

4.1 Ibáñez Formation

4.1.1 Silicic Pyroclastic Rocks

Given the wide distribution of silicic pyroclastic rocks within the Ibáñez Formation, and the common occurrence of reworked pyroclastic material in tuffs and tuffaceous sandstones/siltstones, the description of these rocks is confined to rocks which show field characteristics identifying them as primary pyroclastic deposits and not reworked material. Field criteria used were the presence of well developed columnar jointing, pumice fiamme, massive cliff-forming bedforms, accretionary lapilli, pinch and swell bedding, etc.

Seventy two samples were cut and sectioned, mainly from the larger cliff-forming ignimbritic tuffs but also from bedded tuffs with surge-type pinch and swell bedding or without obvious water-laid bedding, and from pumice flows and lithic tuff/breccia units. Some very thick tuffs (10m or greater) were sampled at base, middle and top to pick up any trends in crystal enrichment, pumice concentration or lithic fragment concentration.

Crystal contents of the tuffs range between 4–50%, but average 22%. The most common minerals present are 0.2–5mm fragments of quartz, albite and sodic oligoclase, with the occasional occurrence of calcic oligoclase, sanidine or high sanidine, consistent with a rhyolitic origin. Accessory and trace minerals include biotite, zircon, apatite and magnetite, often altered to haematite. Quartz crystal fragments are fractured and embayed or rounded beta-quartz paramorphs, and are unaltered apart from occasional overgrowths of secondary mosaic quartz in altered or hornfelsed samples. Plagioclase feldspars are usually fractured and broken subhedral or euhedral crystals, and may be partly or completely sericitised or replaced by calcite, chlorite and clays, or have patchy replacement by K-feldspar. Hornfelsed tuffs have sodic plagioclase altered to saussurite, with granular epidote, sericite and albite pseudomorphs. K-feldspar is difficult to identify, but if present is either sanidine or high sanidine; it is slightly perthitic in some samples, and is less altered than the sodic plagioclase population. Biotite is usually green-brown pleochroic cleavage fragments and booklets, often altered to muscovite in optical continuity with the original biotite, with leucoxene, mosaic quartz or haematite occurring at rims and between cleavage lamellae. Biotite may also be chloritised. Opaque minerals are altered to haematite, goethite and limonite or leucoxene in most samples.

Lithic fragment contents are 1–70%, averaging 14%, but the mode of samples measured was 5%. In most tuffs, lithic fragments range from angular coarse ash to lapilli sizes, but thick ignimbritic tuffs, such as those from the Rio Ibáñez Valley or the Peninsula Ibáñez, include lithic fragments from lapilli to block sizes. Lithic fragments are rhyolitic tuffs, felsitic and spherulitic rhyolitic lavas, and lesser amounts of pilotaxitic and porphyritic plagioclase-bearing dacitic and andesitic rocks. These lithics, which closely resemble Ibáñez Formation lithologies, may be interpreted as local vent-derived fragments or accidental lithic fragments of Ibáñez Formation rocks, picked up during eruptions through vents emplaced into existing Ibáñez Formation material or from the ground overwhich the pyroclastic flows travelled. Some tuffs also contain fragments of hypersolvus granophyric granitoid and coarsely crystalline quartz-albite-muscovite-chlorite greenschists and quartzite. These may be respectively interpreted as cognate magma chamber fragments and xenolithic fragments of basement schists underlying the Ibáñez Formation (Fig. 4.1A).

The vitric or ash and pumice content of Ibáñez Formation tuffs is less easily determined, as most samples are comprehensively devitrified and in many cases recrystallised. The vitric component of the tuffs was determined by assuming that all felsitic textured material and quartz mosaic material present was recrystallised from a vitric ash matrix. This assumption was checked by careful study of thin sections for ghost glass shard and

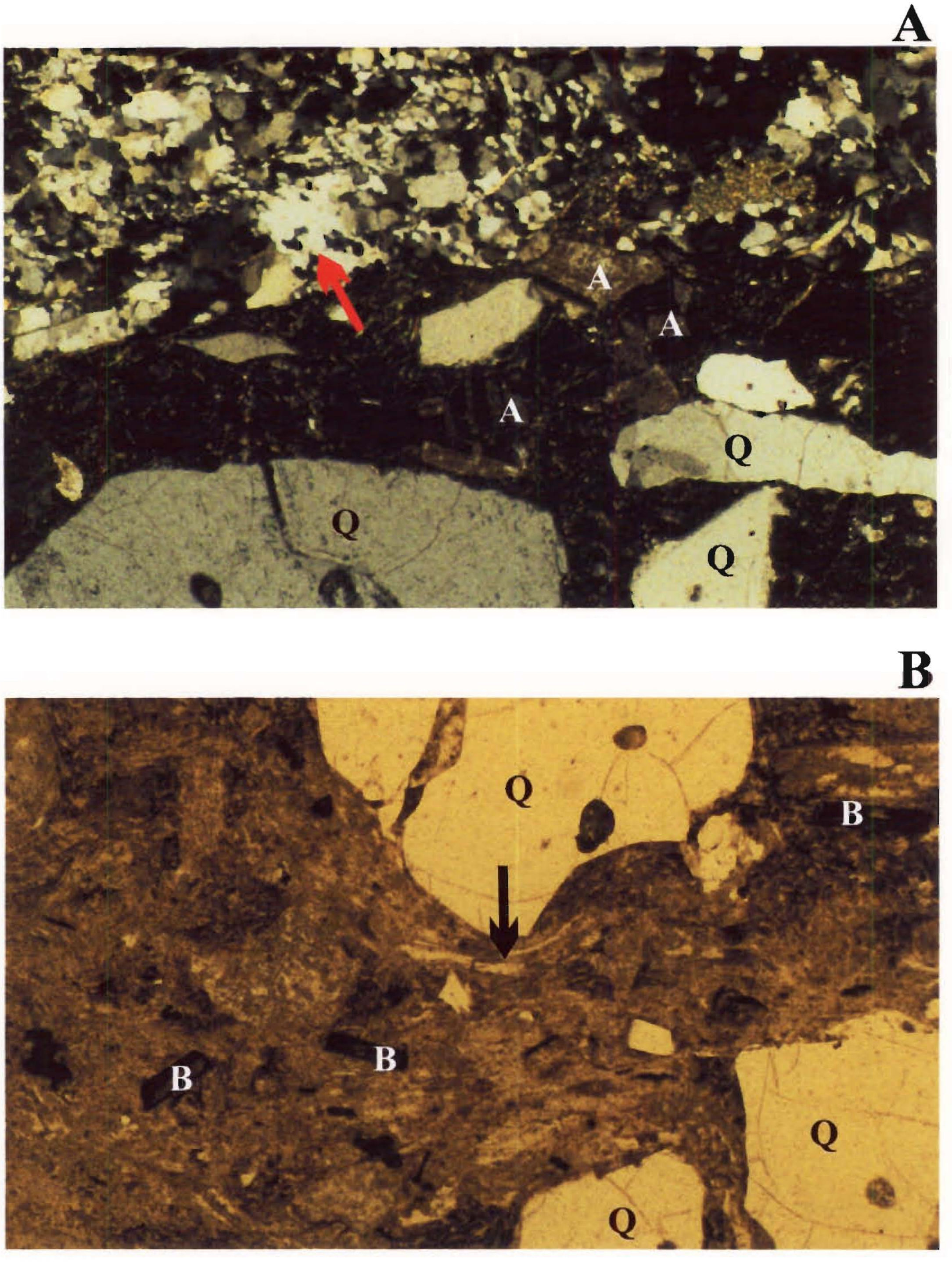


Figure 4.1: A) Photomicrograph of Ibáñez Formation tuff from field location PI 43 M, showing quartzose green schist lithic fragment (arrow), and crystal fragments of quartz (Q), albite (A) in a matrix of felsitic devitrified ashy material (dark matrix). Field of view 5mm, cross polarised light. B) Photomicrograph of relict glass shard textures in Ibáñez Formation tuff from field location WI 56, showing 'wrap around' textures of shards (arrow) against embayed and fractured quartz crystal fragments (Q) and small cleavage flakes of biotite (B). Shard textures are pseudomorphed in fine grained felsitic quartz-K-feldspar intergrowth and sericitic mica. Plane polarised light, field of view 5mm.

pumice textures in plane polarised light. Vitric ash and pumice contents range from 10–90%, with modal and average vitric proportions both being high (74% and 64% respectively). Vitroclastic and eutaxitic textures are only partially preserved, as 'ghost' textures visible in plane polarised light, or as pseudomorphs replaced by alteration products (chlorite, sericite or calcite), or in some samples, by variations in grainsize of the felsitic material recrystallised from original glass (Fig. 4.1B). Pumice fragments are most often replaced by felsitic material, often with a different grainsize from the matrix felsitic material, or by fine grained sericite and calcite. Spherulitic textures occur particularly in pumices but are remnant only, and are overprinted by later development of felsitic or mosaic recrystallisation textures. Felsitic textures are in turn often replaced by mosaic quartz/feldspar textures, especially in contact metamorphosed tuffs near the microgranitic stocks at Cerro Pirámide and Cerro Farellón. Here, original ashy matrix material may show growth of mosaic to granoblastic quartz and feldspars, decussate biotite textures and saussuritisation of plagioclase. Growth of porphyroblasts of epidote, andalusite, biotite, muscovite, and tremolitic amphibole may occur (Fig.4.2A).

Summary

Tuffs in the Ibáñez Formation can be classified as vitric tuffs (Fig. 4.2B). Some crystal-rich samples are either from tuffs above thick ignimbrites and may be crystal-enriched co-ignimbrite ashfalls, or are from the upper parts of massive ignimbritic tuffs and may indicate crystal enrichment as a result of fines winnowing. Massive tuffs identified as ignimbrites by field mapping criteria (massive cliff-forming sheets with columnar jointing, etc.) tend to be lithic-poor, comprising mostly crystal and vitric material. One tuff from the Rio Ibáñez and one from Peninsula Levicán show roughly increasing trends in lithic and crystal fragment content from base to top, coupled with decreasing vitric content from base to top. Thinner bedded tuffs, which could be from either airfall or minor pyroclastic flow or surge activity, show no obvious internal trends in crystal or lithic concentrations. All samples show moderate to extreme alteration, ranging from

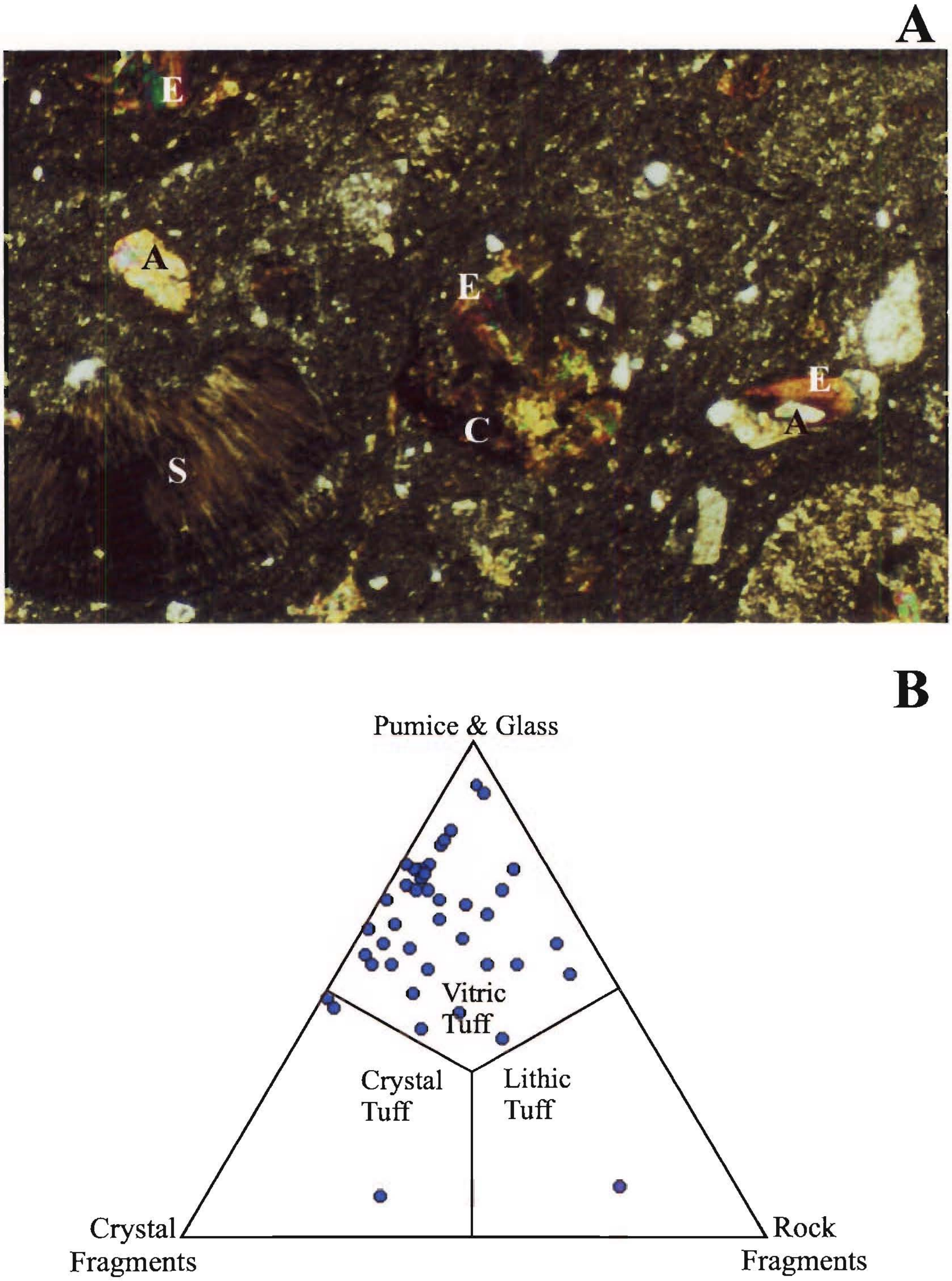


Figure 4.2: A) Photomicrograph of contact metamorphosed Ibáñez Formation tuff from field location PI 100, with granular clusters of epidote (E), chlorite (C) and albite (A) replacing saussuritised plagioclase and forming small porphyroblasts in the devitrified, grey felsitic groundmass. Note also lithic fragment of spherulitic rhyolite (S). Cross polarised light, field of view 5mm. B) Classification plot for ignimbrites and silicic tuffs of the Ibáñez Formation. Fields according to Streckheisen (1979). (Proportions by visual estimation.)

devitrification of original vitric material and weathering of feldspars and mafic phases, through to contact metamorphic recrystallisation, leading to coarsening of devitrification felsitic and mosaic textures and sometimes growth of porphyroblasts, and reach albite-epidote and hornblende hornfels facies.

4.1.2 Silicic Extrusive Rocks (Including Cerro Cabeza Blanca)

In the field, the hand specimen mineralogy and textures of dacitic rocks from Puerto Rey enabled them to be distinguished from the more silicic rocks of the dome complexes of the Cerro Cabeza Blanca, Puerto Ibáñez and West Ibáñez areas. The dacitic rocks lack quartz phenocrysts and spherulitic textures, having instead higher plagioclase contents and distinctive glomeroporphyritic clusters of plagioclase and mafic minerals and commonly, green chloritised mafic phases.

Fifty-two samples were cut for thin sections, including all the main domes or lavas at Puerto Rey, Peninsula Levicán, Peninsula Ibáñez, Cerro Cabeza Blanca, Southwest Cerro Pirámide, and the many small silicic bodies present in the West Ibáñez area (refer Fig. 3.14). Samples were either coherent flowbanded lava, or breccia clasts/fragments.

Dacitic and rhyolitic rocks are porphyritic, with phenocryst content between 5–40% of the total, and with some phenocrysts, generally the feldspars, reaching up to 5mm in size.

Dacite phenocryst populations are dominated by albite and sodic oligoclase (15–40%), followed by a chloritised mafic phase (5–10%), and small amounts of K-feldspar (trace–5%), and up to 5% of oxidised opaque minerals. Quartz was only present as a phenocryst phase in one sample at <5%. Although the mafic phenocrysts were altered in all samples, blocky tabular chlorite/uralite pseudomorphs with occasional octagonal end sections suggest pyroxene pseudomorphs, although one sample also included trace amounts of chloritised biotite.

Rhyodacite and rhyolite phenocryst populations are also dominated by sodic plagioclase, but commonly contain quartz, with ranges of 1–10% quartz, 5–25% albite or sodic oligoclase, and occasionally minor amounts of K-feldspar phenocrysts, usually sanidine (trace-1%). Other phenocryst phases which may be present are biotite (trace-5%) and oxidized opaque minerals (haematite, goethite and leucoxene, 1–5%). Biotite is often partially or wholly altered to pseudomorphs of muscovite, leucoxene and haematite, with exsolved leucoxene and haematite along cleavage planes of the muscovite.

In both dacitic and rhyolitic rocks, trace minerals may include apatite, zircon, magnetite and tridymite, and secondary alteration products may include chlorite, calcite, tremolitic amphiboles, sericite, clay, haematite/goethite, and leucoxene, together with common secondary vein or void-filling quartz, calcite and rarely barytes. Pyrite may occur within any vein assemblages, or as disseminated porphyroblasts in the altered rocks.

Quartz phenocrysts in the rhyolites are subhedral, rounded and embayed 'beta-quartz' high temperature paramorphs, often with slight secondary overgrowths of mosaic or fibrous quartz from groundmass recrystallisation. Some quartz in less altered samples contains partly devitrified glass within embayments.

In both the dacites and rhyolites, albite or sodic oligoclase occurs as euhedral or subhedral crystals, sometimes glomeroporphyritic, commonly altered to sericite or calcite and sometimes showing patchy replacement by K-feldspar or quartz.

The mafic phase in the dacites is uniformly altered to either uralite or chlorite, but based on the shape of the pseudomorphed phenocrysts may have been a pyroxene, possibly orthopyroxene. These pseudomorphs are often in glomeroporphyritic clusters with magnetite, oligoclase and apatite, and are visible in hand specimen as a useful field classification texture. Mafic phases in the rhyodacites and rhyolites are occasionally unaltered biotite phenocrysts (Cerro Cabeza Blanca) but most samples showed alteration of any mafic phase to chlorite and uralite or haematite, leucoxene or sericite.

Groundmass in the dacites ranges (often in the same section) from pilotaxitic textures containing albite-oligoclase microphenocrysts with interstitial quartz and K-feldspar mosaic or poikilomosaic textures, through to dominant quartz and K-feldspar poikilomosaic material around minor patches of pilotaxitic feldspar microphenocrysts. Some samples show remnants of flow banding that has been obliterated by quartz mosaic recrystallisation of the groundmass. Fine grained opaque minerals and oxidised mafic minerals occur throughout the groundmass, either in intergranular textures with the feldspar microphenocrysts, or as inclusions within the poikilomosaic quartz/K-feldspar material (Fig. 4.3A).

Groundmass textures in the rhyolites vary between fine grained felsitic quartz and K-feldspar with faint flow banding and sparse spherulites <1mm across, to coarsely recrystallised poikilomosaic textures with well developed quartz-K-feldspar mosaics around albite and opaque mineral microphenocrysts. Some samples, particularly the coulée lavas from southwest Cerro Pirámide and Cerro Cabeza Blanca, have very well developed coarse spherulitic textures containing individual spherulites up to 10mm across. All rhyolitic and rhyodacitic samples show moderate to extreme mosaic and poikilomosaic recrystallisation of groundmass quartz (Fig. 4.3B and Fig. 4.4A).

Summary

The least altered samples of dacitic and rhyolitic rocks from the Ibáñez Formation have modal and normative values that plot within the dacite and rhyolite fields on a QAPF diagram (see Fig. 4.4B)(Streckheisen, 1979). Most samples show pilotaxitic texture derived from fluid flow in lava and felsitic or occasionally spherulitic groundmass textures indicating extrusion as undercooled lavas. These textures in turn have often been overprinted by mosaic quartz/feldspar recrystallisation and alteration of feldspar and mafic phenocryst phases to sericite, calcite, chlorite, associated with later thermal or hydrothermal effects from the numerous intrusive rocks cutting the Ibáñez Formation.

4.1.3 Basaltic and Basaltic Andesitic Extrusive Rocks

These rocks outcrop as breccias, lapilli tuffs and blocky áa lavas, exposed at El Maitén, Estero Lechoso, Arroyo Zonjón Feo and Southwest of Cerro Pirámide. Thirty-two samples were cut, mainly from outcrops at El Maitén, Estero Lechoso/Cerro Pirámide and Arroyo

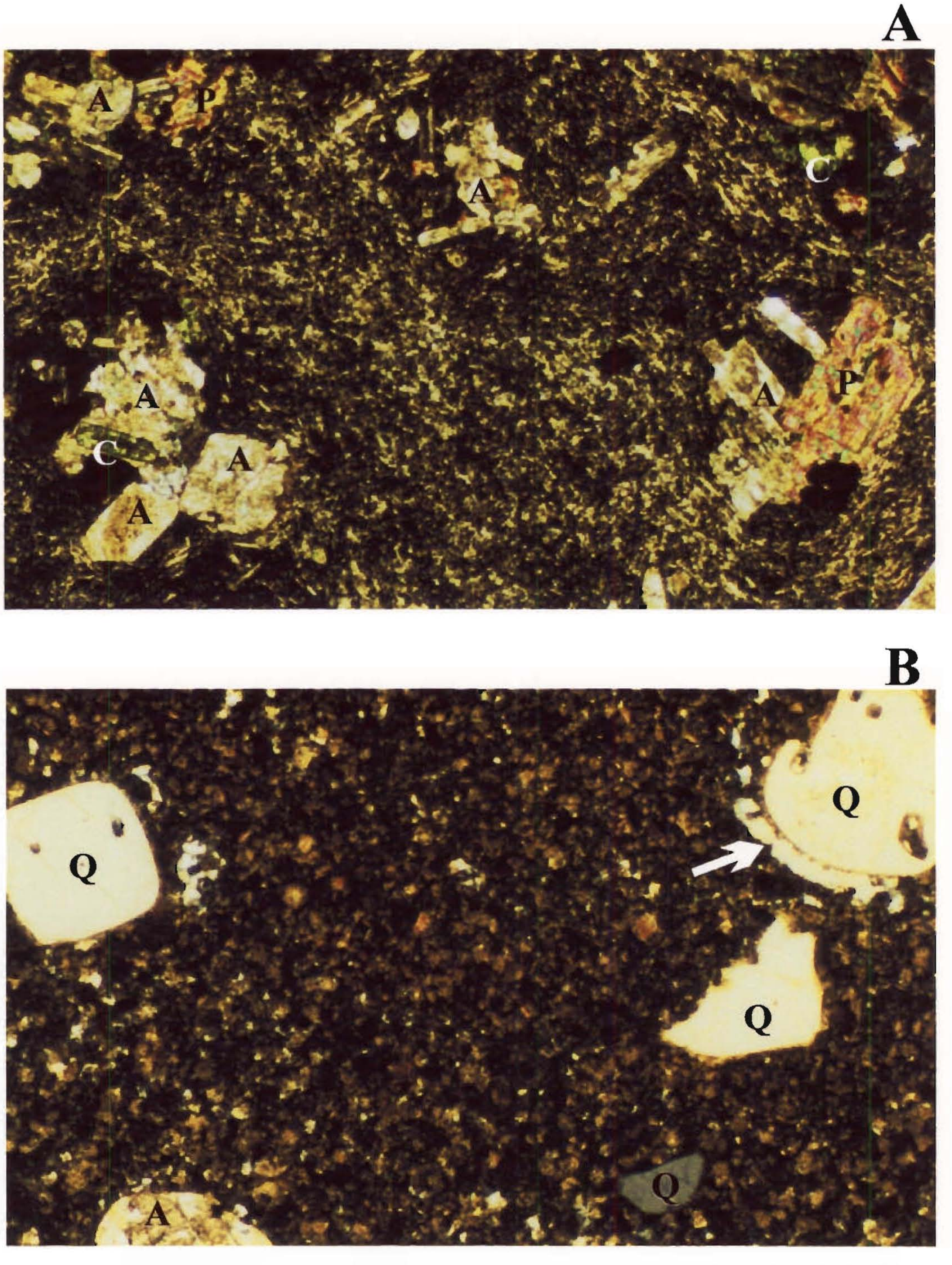
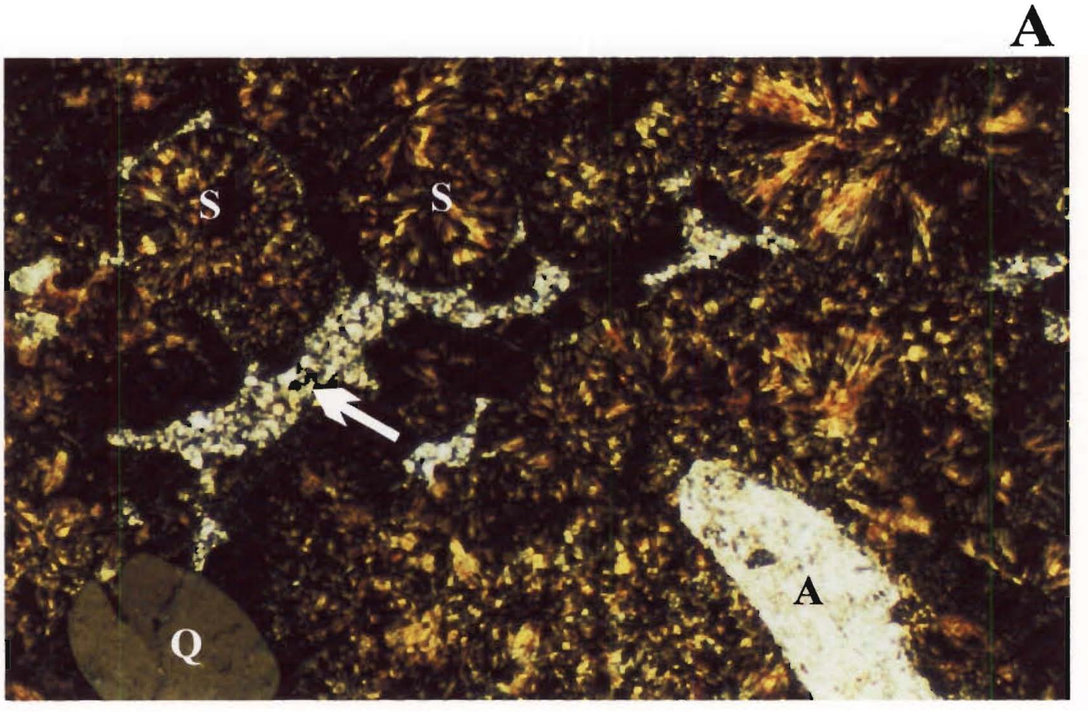


Figure 4.3: A) Photomicrograph of Ibáñez Formation dacitic lava from location WI 111, showing glomeroporphyritic clusters of partly sericitised albite phenocrysts (A) with some magnetite and clinopyroxene (P), usually chloritised (C). Groundmass is fine grained felsitic material with some pilotaxitic texture of feldspar microphenocrysts. Cross polarised light, field of view 5mm. B) Photomicrograph of Ibáñez Formation rhyolitic lava from location WI 76, showing rounded and broken beta quartz paramorphs (Q) with some skeletal overgrowths (arrow) and sodic plagioclase partially replaced by calcite (A, at edge of view) in a brown felsitic groundmass of partially recrystallised quartz-K-feldspar material. Cross polarised light, field of view 5mm.



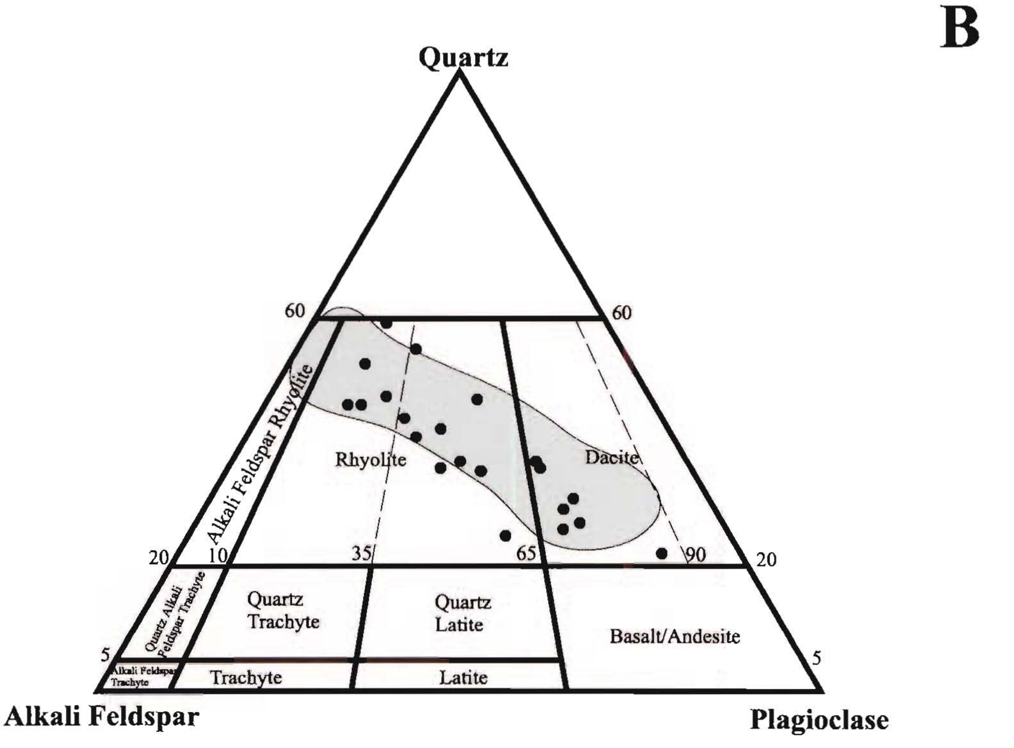


Figure 4.4: A) Photomicrograph of Ibáñez Formation rhyolitic lava from sample GA 11C, with embayed and rounded quartz (Q) and subhedral sodic plagioclase phenocrysts in a groundmass of spherulites (S) with some interstitial felsitic quartz-K-feldspar intergrowths (arrow). Cross polarised light, field of view 5mm. B) QAPF plot for silicic rocks of the Ibáñez Formation. Shaded overlay indicates field of normative compositions of silicic rocks from the Ibáñez Formation. Field names after Streckheisen (1979).

Zonjón Feo, but also from isolated lava flows and breccias outcropping throughout the field area. The rocks range from olivine basalts to basaltic andesites, although identification is difficult due to alteration of the mafic phases.

Áa lavas outcropping at El Maitén are porphyritic olivine basalts, as are some rocks from Estero Lechoso and Cerro Pirámide, whereas lavas from Arroyo Zonjón Feo, Estero Lechoso and west of Puerto Rey are basaltic andesites (see Fig. 4.5A).

Olivine basalts have phenocrysts of altered olivine, clinopyroxene and occasional plagioclase in a matrix of plagioclase feldspar laths with intergranular altered mafic microphenocrysts and magnetite. They retain well developed pilotaxitic textures with intergranular opaques and clinopyroxenes within the groundmass and are sparsely porphyritic (Fig. 4.5B). Olivine phenocrysts range from 3-12% of the total, with a mean of 7%. They are rarely preserved, the 1-2mm subhedral lozenges or skeletal crystals often being pseudomorphed by pale green chlorite or serpentine, with rims of opaque haematite. They are occasionally replaced by chlorite and epidote in contact metamorphosed and altered samples. Clinopyroxene phenocrysts range from 5-20%, with a mean of 12.4%, and occur as 0.5-2mm blocky, rectangular or octagonal pseudomorphs, replaced by fibrous uralite or chlorite, with rims of opaque haematite and leucoxene occurring on some crystals. Cores of some crystals remain unaltered, and in some lavas the finer grained granular clinopyroxenes in the groundmass are only partially altered.

Groundmass plagioclase phenocrysts in the olivine basalts range from 55–75 %, with a mean of 63%. Intergranular phases are altered clinopyroxene, oxidized magnetite and minor quartz. Calcite and chlorite alteration products may form 5-6% of the groundmass of these rocks, and may range up to 15% in more altered or hornfelsic samples, which may also contain additional quartz. Groundmass plagioclase microphenocrysts are euhedral and subhedral laths, often sericitised or albitised, but in less altered samples, compositions range from oligoclase to labradorite, with the least altered samples containing labradorite microphenocrysts. Contact metamorphosed lavas have albitised plagioclase, or replacement by sericite or saussurite with epidote. Clinopyroxene microphenocrysts

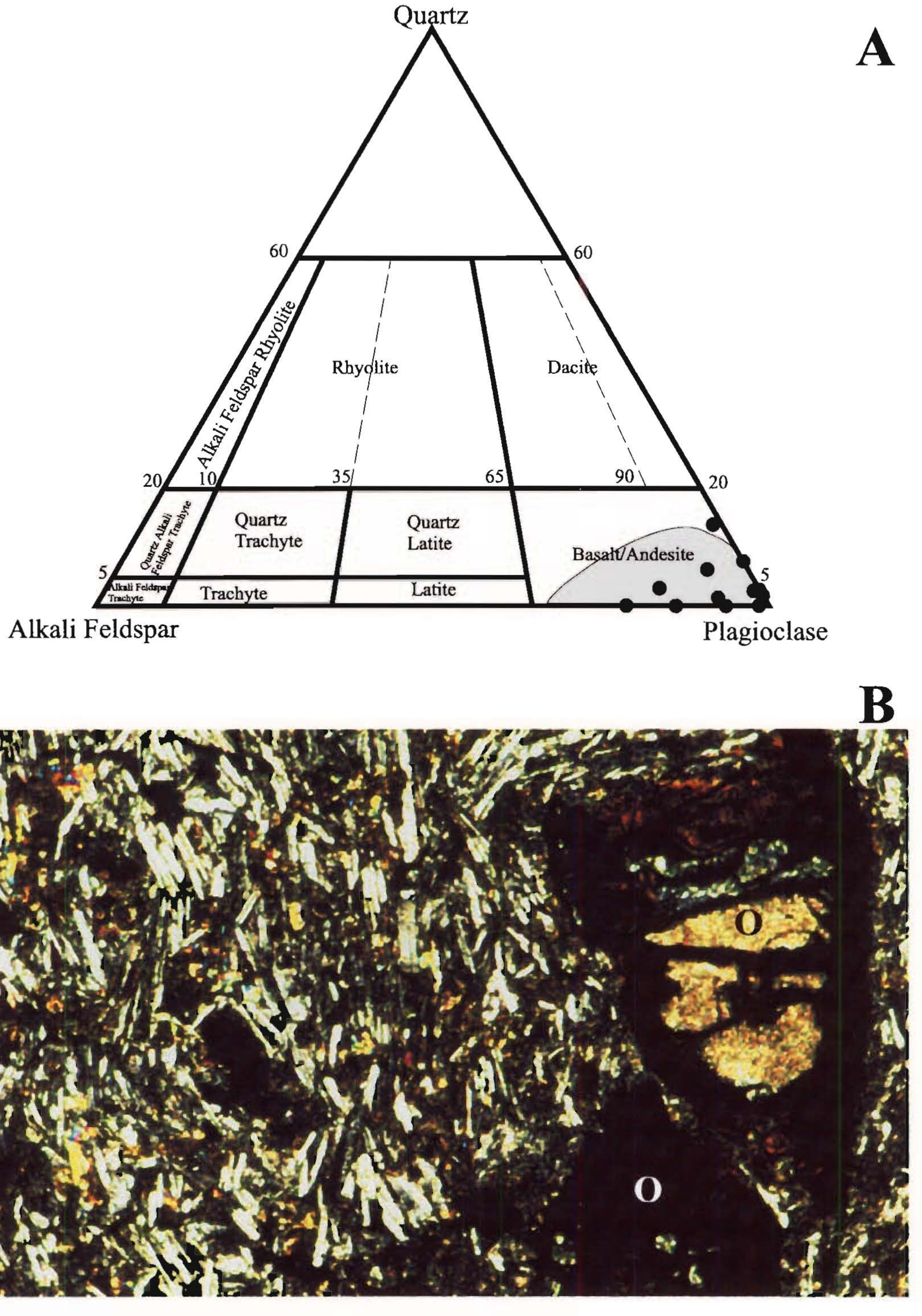


Figure 4.5: A) QAPF plot for Ibáñez Formation basaltic and basaltic-andesitic lavas after Streckheisen (1979). Mineral proportions by visual estimation, overlay field (gray) indicates normative compositions (see chapter 5). B) Photomicrograph of Olivine Basalt from west of El Maiten, sample WI 86A, showing iddingsitised olivine phenocrysts (O) in a groundmass of pilotaxitic labradorite with intergranular magnetite and clinopyroxene (often chloritised). Cross polarised light, field of view 2.5mm.

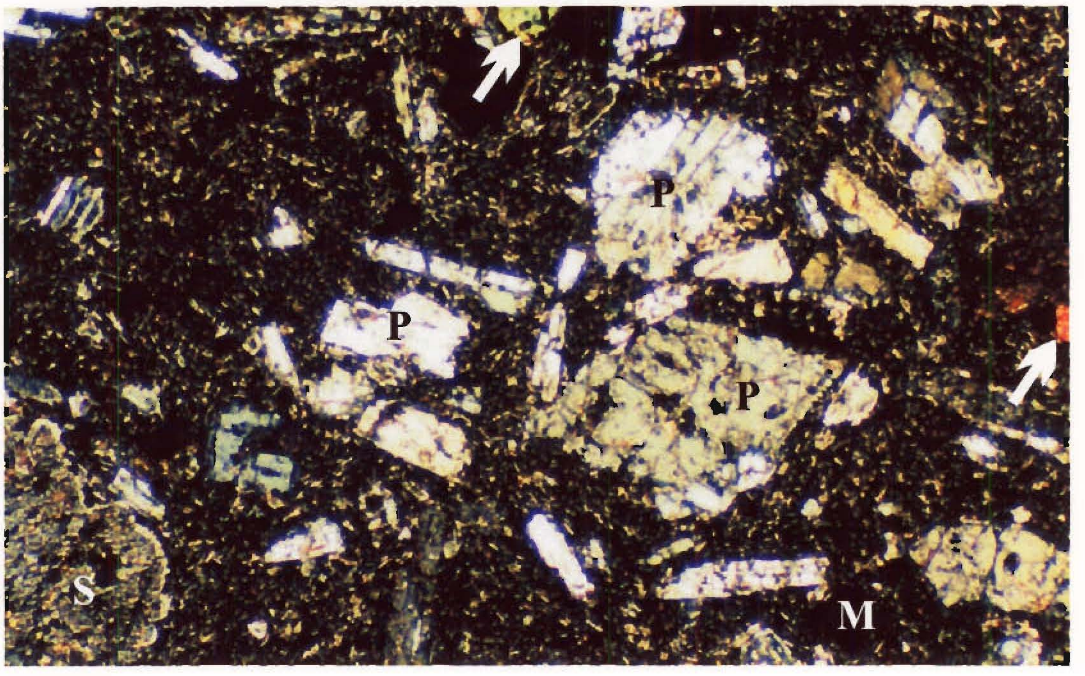


Figure 4.6: Photomicrograph of basaltic andesite lava from Arroyo Zonjon Feo, sample F28, with oxidised and chloritised clinopyroxene (white arrows), magnetite (M) and normally zoned labradorite-andesine plagioclase phenocrysts (P), sometimes sieve textured (S), in a fine grained matrix of pilotaxitic andesine with intergranular clinopyroxene, magnetite and fine interstitial K-feldspar (not visible). Cross polarised light, field of view 5mm.

are unaltered in some lavas, but most are wholly or partly uralitised or chloritised, or replaced by carbonates. In some contact metamorphosed rocks, pyroxenes are replaced by chlorite, iron oxides and epidote. Opaque minerals, mainly magnetite and haematite, range from 5-10% in most samples, but up to 30% in altered examples. They occur as fine intergranular microphenocrysts within the groundmass, and as alteration products of the mafic phenocryst phases.

Basaltic andesite lavas are porphyritic, vesicular rocks, with phenocryst phases of plagioclase, clinopyroxene and magnetite in a pilotaxitic groundmass of plagioclase laths with intergranular pyroxene and magnetite (Fig. 4.6).

Plagioclase ranges from 53-70% averaging 62%. Phenocrysts are euhedral to subhedral crystals, up to 5-6mm, often zoned and ranging from calcic labradorite in cores to andesine or sodic oligoclase at rims. They are often glomeroporphyritic or seive textured.

Groundmass plagioclase is pilotaxitic subhedral laths <0.5mm, often with swallowtail morphology and of similar composition to phenocrysts, but ranging to andesine or more sodic oligoclase in some samples. Altered samples have sericitised, albitised and saussuritised phenocrysts, or calcite replacement of plagioclase, often in combination with patchy or network replacement by K-feldspar along fractures and cleavage planes. Clinopyroxene is rarely preserved, being replaced by chlorite, fibrous uralite or calcite and iron oxides. Pseudomorphs are euhedral to subhedral phenocrysts from 0.5–3mm, and can be used to estimate the original proportions, which range from 5–20%. In at least one sample, remnant phenocrysts allowed identification of trace amounts of orthopyroxene phenocrysts in addition to clinopyroxene, but the true proportions of the two pyroxenes in these rocks are difficult to determine due to the pervasive chloritisation or uralitisation of the mafic minerals. The opaque phase of both phenocrysts and groundmass in these rocks is magnetite, often oxidised and replaced by haematite and leucoxene. It forms 5-25%, averaging 13%, but a large proportion are secondary alteration products of the mafic minerals, and not primary magnetite.

Summary

These samples plot in the basalt/andesite field on a QAPF plot (Le Maitre, 1989) (Fig. 4.5A). They are roughly separable into two groups, as olivine basalts based on the occurrence of altered pseudomorphs of olivine, and as basaltic andesites when lacking olivine and showing occasional evidence of coexisting augite and orthopyroxene. Given the high degree of alteration and the common albitisation of plagioclase, it is likely that mobility of Na in these rocks is high, possibly with addition of Na from seawater during the marine transgression of the latest Jurassic- early Cretaceous, possibly leading to some degree of Na-metasomatism of these and other Ibáñez rocks.

4.2 Coyhaique Group

4.2.1 Katterfeld Formation

Three samples of the Katterfeld Formation blackshales were cut for petrography. These were from the disrupted outcrops cut by hypabyssal intrusive rocks at Estancia Moroma (GR 283314 4868800); from sheared and disrupted outcrops cut by the Cerro Farellón microgranitoids in the headwaters of the Estero Lechoso north of Laguna Huncal (GR 278000 4876940), and the third within the metamorphic aureole of the Cerro Farellón microgranitoid at Cerro Farellón (GR 272832 4878335).

The Estancia Moroma and Laguna Huncal/Cerro Farellón samples of the Katterfeld Formation are both finely laminated shales/mudstones, with normally graded laminations of fine grained semi-opaque mud/clay. Carbonaceous opaque organic material and a minor quartz-feldspar silt component are present, and there are occasional andesitic rock fragments up to 1mm. The andesitic material is rare, and may represent either material eroded from exposed portions of the underlying Ibáñez Formation or possible contemporaneous andesitic volcanism during Katterfeld Formation deposition. The laminations around a rock fragment in one sample show impact deformation, indicating its emplacement as a small 'dropstone', presumably from sediments on floating vegetation/treestumps. Calcite veins may cut across the laminations and at Estancia Moroma have deformed some laminations, forming convoluted laminae and calcite veins. This may have been due to compaction while the sediment was unconsolidated. The laminae cutting calcite veins themselves are contorted in tight sigmoidal folds, and cut by a second generation of undeformed veins which run parallel to the laminations. There are some dissolution or pressure solution seams, especially noticeable where the sigmoidally folded calcite veins are present. In the tectonised sample from Laguna Huncal, there are thin discontinuous carbonate layers or concretions up to 2cm thick, draped with silty and muddy carbonaceous layers. These layers show spotty growth of dolomite in a matrix of sparry calcite with wedge-shaped fractures filled with recrystallised calcite. These concretion layers may be recrystallised from the lime muds that formed the fossiliferous hardgrounds observed in the field outcrops.

The Cerro Farellón sample of the Katterfeld Formation is also a finely laminated shale, but has a greater proportion of silty material present as migrating ripples. It has been thermally metamorphosed by the nearby Cerro Farellón microgranitoid. The blackshale adjacent to the micrograniteid is a hard silicified and hornfelsed laminated mudstone to fine siltstone. Laminations are 0.5–3mm, with finer muddy laminations partially recrystallised to fine grained sericitic mica with strong lamination parallel lattice preferred orientation. Coarser silty layers include partly mosaic recrystallised quartz/feldspar grains and cherty rock fragments in a silty matrix. Incipient 'spotty' porphyroblast growth is observable as pleochroic round haloes free of fine micas, around small <1mm green pleochroic grains, possibly green actinolitic amphibole, but the metamorphic mine grains are small and difficult to identify. Quartz veins have 0.5mm muscovite grains as fringes along the vein margins. Carbonaceous material is much less obvious than in the Estancia Moroma sample, but is present as very fine grained opaque material, concentrated in the muddy layers.

Silty laminations are composed of cherty rock fragments with about 20–30% quartz and sodic plagioclase fragments up to 0.3mm, and have a matrix of cherty and micaceous material. Coarser grained (0.3–0.4mm) silty to fine sandy layers with ripple shapes and faint low angle crossbedding have granular or radial clusters of blue-green or brown-blue pleochroic actinolitic amphiboles. Opaque euhedral pyrite porphryoblasts are disseminated throughout in both silty and muddy layers. Some microfaults occur, with normal displacements of up to 2mm and secondary quartz and mica fringes grown along the fracture surface.

Summary

The Katterfeld Formation black shales in the Puerto Ibáñez Quadrangle are finely laminated carbonaceous mudstones and siltstones with occasional development of fine sandstone beds and isolated ripples, sparse andesitic detrital material, and secondary calcite concretions and diagenetic calcite veins. The presence of andesitic material may indicate active Hauterivian volcanism near the Aysén Basin, but the low levels of andesitic material found may equally be derived from eroded material of Ibáñez Formation provenance. They have undergone both soft sediment deformation during compaction and diagenesis, together with brittle fracture and shearing during later igneous intrusion. Where they are intruded by rocks of dacitic composition, and in particular by the microgranitoids at Cerro Farellón and Cerro Pirámide, local thermal metamorphism has converted them to hornblende hornfels facies, with the development of small porphyroblasts of pyrite, granular blue-green hornblende, and recrystallisation of the muddy portion of the shale to fine grained sericitic muscovite.

4.2.2 Apeleg Formation

Six samples from the Apeleg Formation were cut, one from relatively unaltered but disrupted sediments at Estancia Moroma, and five from within the metamorphic aureole of the Cerro Farellón microgranitoid.

At Estancia Moroma, sandstones from the Apeleg Formation are locally overturned and tectonised both by reverse faulting and inclusion as roof pendants in a small hypabyssal intrusion. This rock is white or grey, medium and coarse sandstone in hand specimen, well sorted and thickly bedded with both normal and reverse grading of the beds. In thin section it is a clast supported sandstone dominated by sub-equal amounts of quartz grains and rock fragments, with subordinate feldspar grains. Quartz grains are sub-rounded volcanic quartz, with some diagenetic quartz overgrowths visible over dust rims at the grain edges. Rock fragments are mainly fragments of silicic volcanic rocks, with felsitic and quartz-mosaic recrystallisation textures, and some pilotaxitic andesitic rock fragments also occur. Feldspar grains are sub-angular to sub-rounded broken volcanic crystal fragments, mainly sodic plagioclase, either albite or oligoclase, which are murky and often partially altered to sericite. Much of the rock is partially cemented by secondary quartz overgrowths or cherty material, which could be due to alteration/devitrification of the silicic rock fragments, and there is also some growth of sericitic muscovite between grains. Calcite occurs as a void filling material.

The samples from the northwestern slopes of Cerro Farellón have slight to moderate alteration due to the thermal effect of the adjacent and underlying Cerro Farellón microgranitoid.

Immediately adjacent to the microgranitoid, the sandstones are hard, granular black or grey hornfels with very little remnants of original sedimentary structures. Relict feldspar sand grains are visible in thin section, but most rock and quartz fragments have been replaced with mosaic quartz and decussate biotite, that also occurs as rims around relict grains. Small porphyroblasts of pyrite and granular brown-green or blue-green pleochroic amphiboles, either green actinolite or hornblende, also occur associated with the biotite, indicating either albite epidote or perhaps hornblende hornfels facies conditions for the thermal metamorphism immediately adjacent to the granitoid. Traces of muscovite occur within the mosaic quartz and feldspar, and also as sericitic material replacing relict feldspars. Veins cutting the hornfels have green pleochroic chlorite along rims and scapolite as vein or void filling material, indicating the presence of high $CO2/SO2/Cl-$ pressure, probably derived from briny pore space fluids, during contact metamorphism (Deer et al., 1992).

At greater distances from the microgranitoid, up to 100m from the contact, the Apeleg Formation lacks the pervasive destruction of sedimentary features described above. Bedding and detrital textures are still in place in hard, silicified epidote bearing 'spotty' hornfels rocks. Three samples are from poorly to moderately sorted, clast supported fine to coarse sandstones and granule to fine pebble conglomerates. They come from thickly bedded, foreset crossbedded, medium and coarse sandstones and fine pebble conglomerates with some intervening thin fine sandy or silty mudstones. In thin section, detrital textures are still present, although silicic volcanic or tuffaceous rock fragments are often recrystallised to mosaic quartz, or spotted with clusters of granular epidote, magnetite, pyrite and chlorite. Andesitic rock fragments are also partially recrystallised to cherty or mosaic quartz textures, but many grains retain relict feldspars and pilotaxitic textures. Feldspar grains are mainly subangular fractured grains of volcanic sodic plagioclase, with sieve textures occasionally present and albite-carlsbad twinning is common. K-feldspar is relatively rare. Feldspars are often murky and altered and may be partially sericitised or albitised with development of epidote and sericite. Quartz grains occur as both volcanic beta quartz fragments and rarely as well rounded grains and granules of polycrystalline metamorphic quartz and quartz/mica rock fragments. Both types of quartz grain show overgrowths of coherent and cherty quartz on dusty rims. Mosaic and cherty quartz also occur as void filling and cement, along with chlorite and epidote. Volcanic quartz grains are angular and subrounded, with some still showing embayments and primary igneous shapes, as do remnant feldspars, indicating a relatively immature, local provenance, whereas the sparse metamorphic polycrystalline quartz rock fragments are very well rounded, indicating greater maturity and more distant provenance. Some of these samples contain green hornblendes and can be assigned to the hornblende hornfels facies, whereas in others, the main metamorphic minerals are epidote, chlorite and albite, indicating an albite-epidote facies.

A sample of the Apeleg Formation taken approximately 500m from the microgranitoid shows the least alteration that can be ascribed to thermal metamorphism. This rock is a moderately to well sorted, clast supported, medium to coarse sandstone with foreset crossbeds. Normal and reversely graded crossbed laminae and 5–50mm ripup clasts of fine siltstones and mudstones are present. In thin section, sand grain composition is similar to that described above, with common volcanic quartz and occasional metamorphic quartz fragments, altered and sericitised volcanic sodic plagioclase, and rock fragments of silicic tuffaceous rocks, silicic volcanic rocks and andesitic rocks. Chlorite occurs as a void filling mineral, but this rock is without mosaic quartz cementation or quartz grains with visible overgrowths. Ripup clasts are large, angular fragments of silty mudstone, and are partly deformed, indicating a lack of lithification when emplaced and implying a local source. Silicic tuffaceous sedimentary rock fragments and silicic volcanic rock fragments

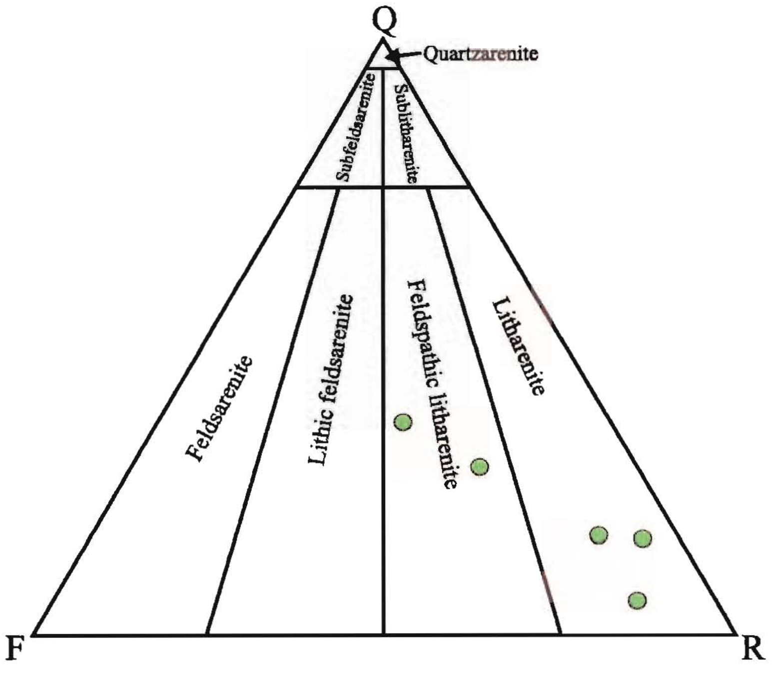


Figure 4.7: QFR plot for five sandstones of the Apeleg Formation of the Coyhaique Group, after Folk et al. (1970).

are partly recrystallised to felsitic or cherty textures, whereas andesitic rock fragments still show pilotaxtic textures with altered sericitic feldspars and oxidised mafic and opaque minerals.

Summary

Sandstones from the Apeleg Formation in the Ibáñez Quadrangle plot on a QFR triangle as feldspathic litharenites and litharenites, and can be interpreted as immature sandstones with a dominantly volcaniclastic detrital input and a minor amount of mature metamorphic quartz sand grains (Fig. 4.7). They are affected by intrusive rocks in several locations, leading to effects ranging from recrystallisation of feldspars and silica cementing of quartz grains to albite-epidote and hornblende hornfels facies at their contacts with the Cerro Farellón microgranitoids.

4.3 Divisadero Formation

4.3.1 Tuffs and Ignimbrites

These rocks occur throughout the Divisadero Formation in the Ibáñez Quadrangle, and were also sampled at measured sections from Cerro Divisadero, Cerro Montreal, Lago Castor, and Lago Frio. Fifty samples were cut, mainly from massive cliff-forming tuffs and ignimbrites in the measured sections. As with the Ibáñez Formation, some of the massive ignimbrites were sampled at base, middle and top to pick up internal textural changes.

Divisadero Formation tuffs show much lower crystal and lithic contents than many of the samples from the Ibáñez Formation, with crystal contents ranging from 0.5–37%, and an average of 13.4%. Crystal fragments are generally less than 5mm in size, and in tuffs from Cerro Divisadero were particularly small and sparse (<1%, <3mm). Tuffs from the Ibáñez Quadrangle have higher crystal contents and show a greater range of crystal fragments than those in the Coyhaique region. Quartz, sodic plagioclase (oligoclase and albite), occasional sanidine or high sanidine and traces of biotite, apatite and magnetite as accessory minerals occur in the Ibáñez tuffs, whereas tuffs from the measured sections in the Coyhaique region often have a lower crystal content and some lack quartz, although the feldspars are still present (Fig. 4.8).

Quartz crystal fragments are unaltered whereas plagioclase feldspars are often altered partially or wholly to sericite or calcite, or in some cases replaced with patchy K-feldspar along cleavage planes and fractures. Biotite occurs as occasional cleavage fragments or 'booklets' and is green-brown pleochroic. It may be partially or wholly chloritised, or in some cases replaced with a mixture of coherent muscovite with opaque haematite and leucoxene between cleavage planes. Within those tuffs sampled at base, middle and top, crystal contents tend to be highest in the base or middle samples and lowest at the top, although some samples showed higher crystal contents in the upper samples.

Lithic fragment content is low, from 0–8%, with an average of 2.4%. Lithic fragments are generally small lapilli (<30mm), although some tuffs in both the Ibáñez Quadrangle

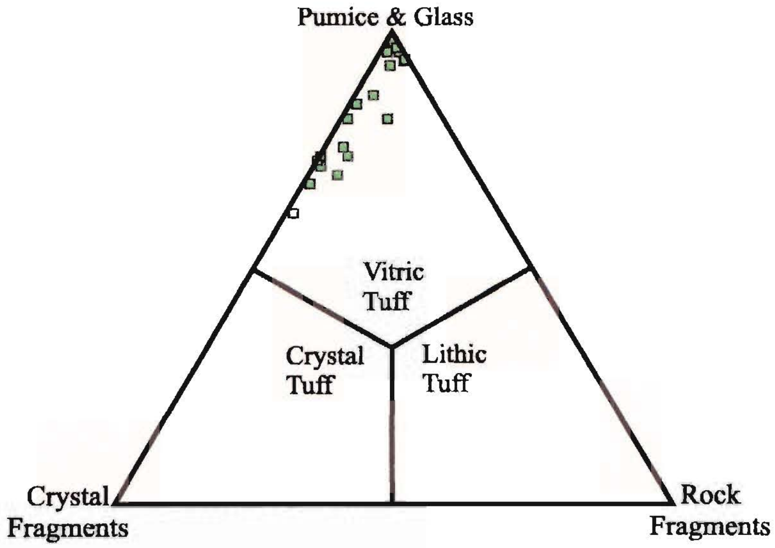


Figure 4.8: Classification plot for ignimbrites and silicic tuffs of the Divisadero Formation. Fields according to Streckheisen (1979). Mineral proportions by visual estimation.

and Coyhaique region contain block and bomb size fragments, with one tuff in the Cerro Montreal measured section containing megablocks in excess of 10m. Divisadero Formation tuffs and ignimbrites lack fragments of basement schists, the lithic fragments usually being either tuffs, tuffaceous sediments, spherulitic or felsitic rhyolites, or occasionally andesitic fragments. Silicic lithic fragments are often partially devitrified to felsitic textures, and in some cases have mosaic quartz-K-feldspar growth. Andesitic lithic fragments are oxidised, with replacement of mafic minerals by haematite. In those Divisadero Formation tuffs from Cerro Divisadero, Lago Frio and Lago Castor which were sampled at base, middle and top, there is often a slight but noticeable increase in lithic and crystal fragment content in samples from the base and middle, whereas vitric material tends to increase towards the top. No clear trend in lithic or crystal fragment contents was present for rocks from the Ibáñez Quadrangle.

Tuffs from the Divisadero Formation have less devitrification and alteration of vitric material in most samples than do Ibáñez Formation tuffs. Pumice, glass shards and vitroclastic textures are often well preserved, with good eutaxitic textures and pumice fiamme, although the degree of devitrification and alteration varies widely. The vitric

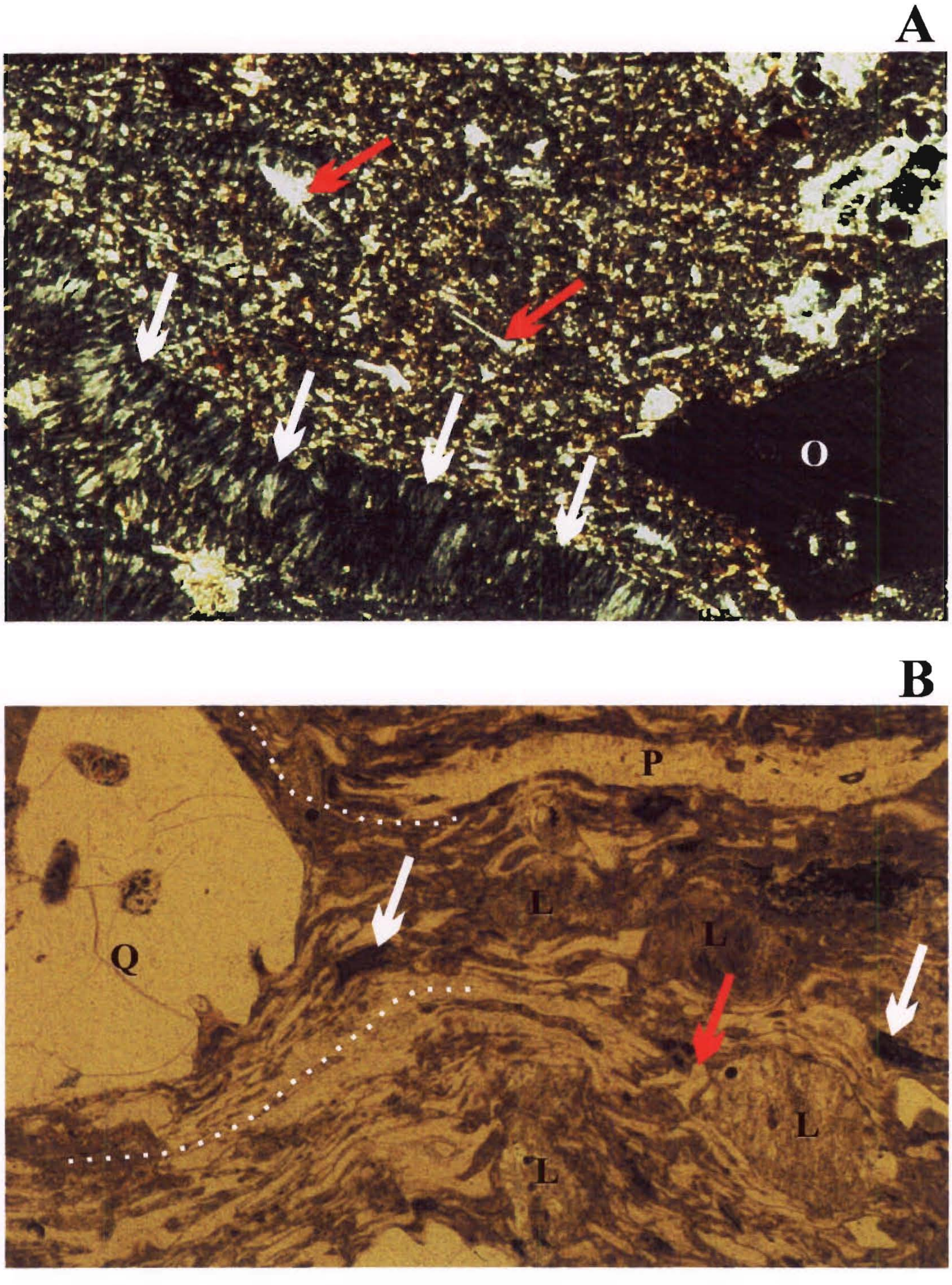


Figure 4.9: A) Photomicrograph of Divisadero Formation tuff from east of La Pedregasa, sample F48, with an oligoclase crystal fragment (O), irregular spherulites developed in pumice fiamme (white arrows) and a felsitic groundmass of recrystallised ashy material with some relict glass shards (red arrows). Cross polarised light, field of view 2.5mm. B) Photomicrograph of Divisadero Formation ignimbrite from the top of the Cerro Manchón cross section, sample CF 39, showing relict glass shards (red arrow) with 'wrap around' structure (dotted line) around an embayed quartz fragment (Q), pumice fiamme with ragged terminations (P) and some biotite cleavage flakes (white arrows). Lithic fragments are also present (L). Plane polarised light, field of view 5mm.

content of Divisadero Formation tuffs and ignimbrites ranges from 62–98%, averaging 84%. Tuffs from the Coyhaique region measured sections tend to have higher vitric contents than those from the Ibáñez Quadrangle, and vitric material tends to increase in proportion towards the upper parts of tuffs at the expense of crystal and lithic contents. Tuffs from the Ibáñez Quadrangle show a range of devitrification textures, with both groundmass vitroclastic material and pumice fiamme wholly or partly recrystallised to felsitic textures, or to quartz-K-feldspar mosaic textures. In this latter case, vitroclastic textures are more visible in plane polarised light (Fig. 4.9B), and in cross polarised light are only visible due to grainsize variations in the felsitic material between finer grained matrix and larger shard fragments. In some samples, recrystallisation is so complete as to almost obliterate any shard textures. Fine grained haematite may also replace or outline shard textures. More altered samples may show fine grained sericite or chlorite mica as replacement of vitric material and pumices, or as fine networks grown throughout an originally ashy matrix. Tuffs from the Divisadero Formation in the Coyhaique region show very well preserved vitroclastic textures and pumice fiamme, often with excellent eutaxitic textures, but some samples also have near complete obliteration of vitroclastic textures by devitrification. Tuffs from the Coyhaique region may show a range of preservation of original textures, from unaltered isotropic glass shards with some spherulite growth, through to partial or complete devitrification to felsitic and spherulitic textures, again with 'ghost' preservation of shard and pumice textures by grainsize variations in the recrystallised material (Fig. 4.10).

Summary

Tuffs sampled from the Divisadero Formation are exclusively vitric tuffs (Fig. 4.8), and show a lower level of lithic content than tuffs from the Ibáñez Formation, although the ranges of crystal content and vitric content are similar. This may reflect a more distal setting with respect to eruptive centres than those in the Ibáñez Formation. The Divisadero Formation tuffs are less altered than those of the Ibáñez formation, and show a

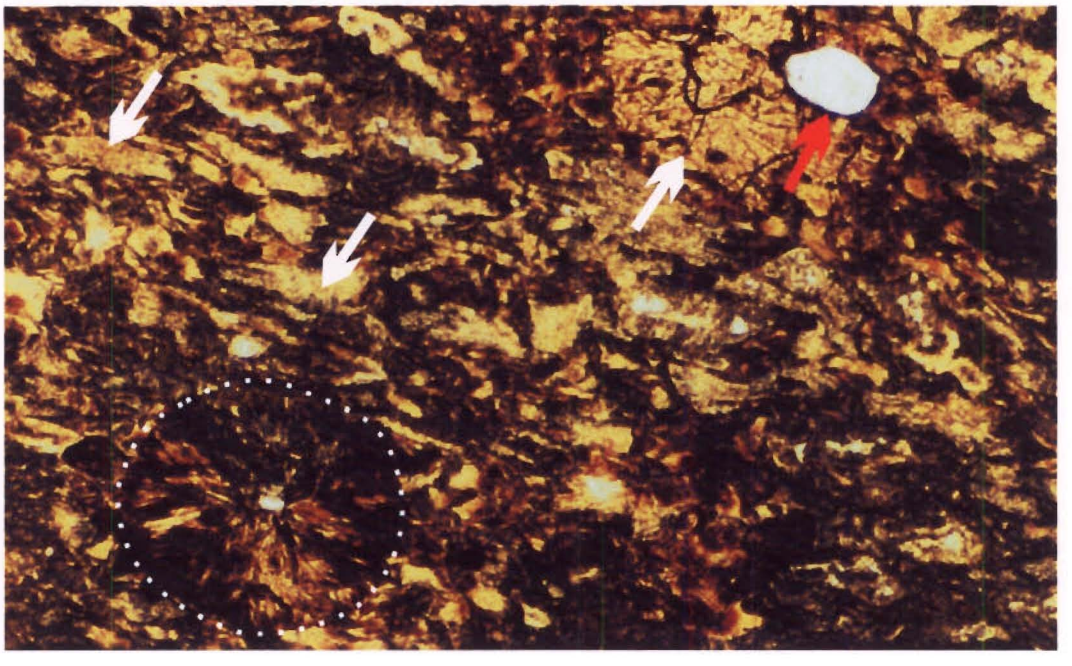


Figure 4.10: Photomicrograph of Divisadero Formation tuff from Cerro Divisadero, sample CD 12, showing partly devitrified eutaxitic glass shard textures with some large remnant pumice fragments (white arrows), quartz crystal fragment (red arrow) and a spherulite nucleated on a small albite crystal fragment (dotted line). Plane polarised light, field of view 5mm.

range of devitrification textures from unaltered or slightly altered glassy eutaxitic welded ignimbritic textures through to felsitic and spherulitic devitrification textures that may partly or wholly replace original vitroclastic and eutaxitic textures.

4.3.2 Andesitic Lavas

One basaltic andesite lava occurs in the Divisadero Formation in the Ibáñez Quadrangle, at GR 286700 4872150, above Estancia Moroma between Cerro Pico Rojo and Cerro Cabeza Blanca. The rock is porphyritic, with about 20% of 1–4mm altered and albitised seive textured plagioclase phenocrysts and sparse augite phenocrysts, in a groundmass of pilotaxitic andesine microphenocrysts, <0.1mm, with intergranular magnetite, altered augite, 2–3% interstitial anhedral quartz and 5–10% anhedral K- feldspar; K-feldspar also occurs as rims on plagioclase microphenocrysts. There is commonly secondary haematite, calcite, chlorite and bright green celadonite as alteration products. This rock plots in the basalt/andesite field of the QAPF diagram of Streckheisen (1979) and is tentatively identified as a basaltic andesite on the basis of the groundmass andesine and the lack of olivine as a phenocryst phase.

4.4 Cerro Pico Rojo Rhyolite

These rocks outcrop as partially dissected lava dome remnants in the peak of Cerro Pico Rojo and across Estero Zonjón Feo immediately to the north, and also occurs as a small inlier of rhyolite between the basaltic andesite intrusion to the north and the overlying Plateau Basalts (GR 284500 4878500). Eight samples were cut, one pumice flow underlying the main lava dome at Cerro Pico Rojo, one obsidian from the edge of Cerro Pico Rojo and six samples of rhyolite lava from the main lava dome and the smaller outcrops.

4.4.1 Dome and Coulée Lava Fragments

The obsidian sample from the eastern margin of Cerro Pico Rojo is a red stained, flow-banded rock, sparsely porphyritic with occasional phenocrysts of albite and sanidine feldspar, in a matrix of red and white banded, partially devitrified obsidian. Feldspar phenocrysts comprise <5% of the rock, occurring as euhedral phenocrysts, <1.5mm in size. Albite phenocrysts are sometimes in glomeroporphyritic clusters, whereas sanidine occurs as stubby euhedral crystals (Fig. 4.11A). The obsidian matrix is stained a deep orange to red, commonly with perlitic fracturing, and with devitrification occurring as individual spherulites or as bands of elongate spherulitic material parallel to flowbanding. Void spaces and perlitic cracks may be filled with opaque iron oxides or bright green chlorite.

Lavas from the Cerro Pico Rojo Rhyolite are either sparsely porphyritic or aphanitic flowbanded rocks, and may have phenocrysts of quartz and sanidine in a felsitic matrix with varying degrees of recrystallisation to mosaic quartz-feldspar textures. Quartz phenocrysts and microphenocrysts, if present, may range from 0–20% of samples, are subhedral and generally <0.5mm, although large 0.5–3mm bipyramidal quartz phenocrysts are present in one sample from the core of Cerro Pico Rojo. Sanidine phenocrysts range from 0–20%, but usually comprise about 5% of the rocks. Sanidine phenocrysts may be euhedral or subhedral fractured crystals. Large (1–3mm) granitic textured xenoliths composed mainly of slightly perthitic K-feldspar occur in one lava, and are interpreted as cognate K-feldspar granite xenoliths.

The groundmass of the lavas is dominated by felsitic material (75–97%), often partially recrystallised to cherty quartz-feldspar mosaics, with subordinate microphenocrysts of quartz, sanidine and occasional blue-green pleochroic sodic amphiboles, probably riebeckite. Sanidine microphenocrysts may show pilotaxitic textures in the groundmass. Opaque haematite/goethite occurs as void filling and staining, particularly along flowbanding or fractures, and chlorite occurs as void filling in one sample. Some samples have well developed poikilomosaic textures with orientated sanidine microphenocrysts, whereas others

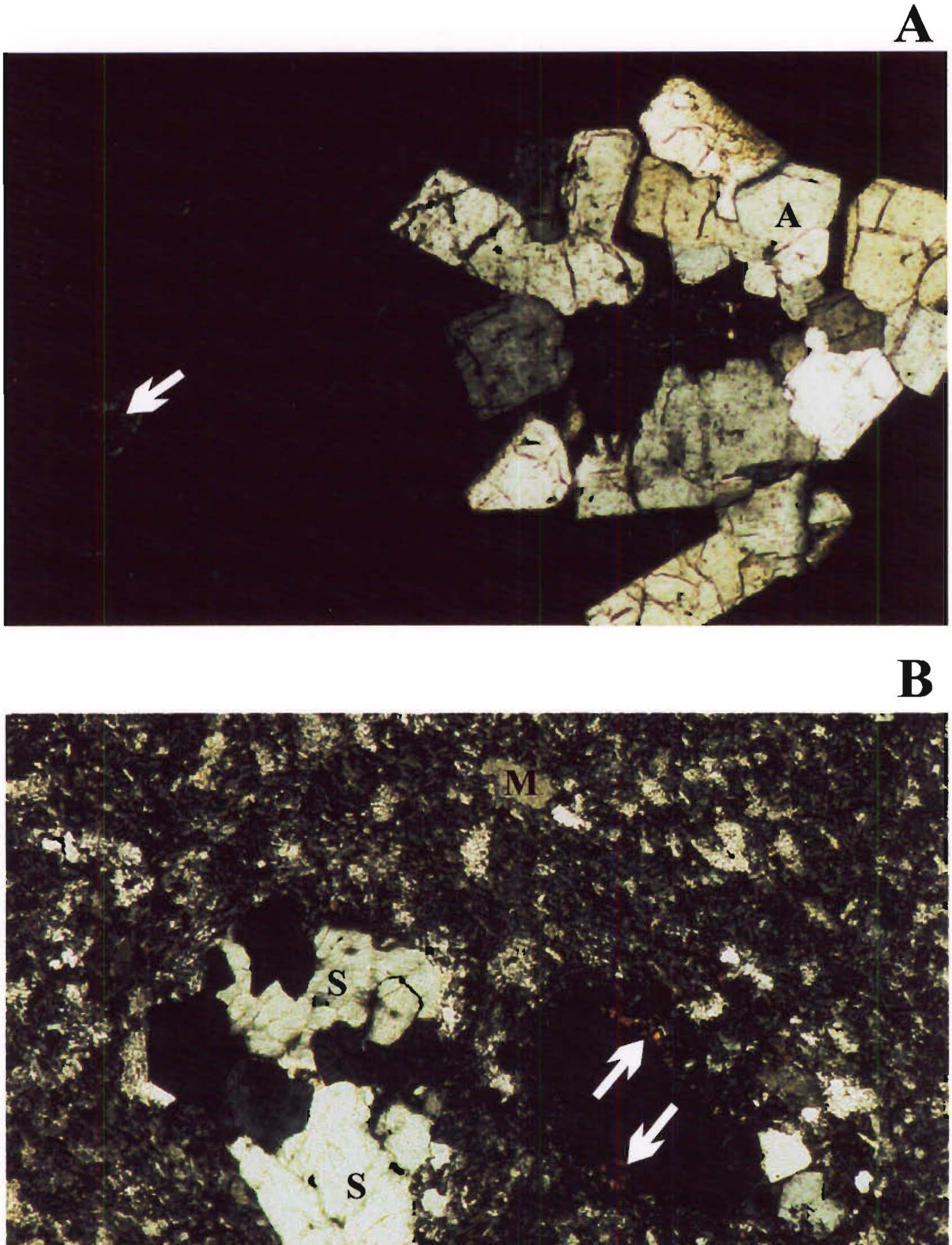


Figure 4.11: A) Photomicrograph of Cerro Pico Rojo obsidian, from the western edge of the dome, sample S2, showing glomeroporphyritic albite phenocrysts (A) in an isotropic matrix of opaque glass, with a faintly visible spherulite (white arrow). Cross polarised light, field of view 5mm. B) Photomicrograph of lava from the Cerro Pico Rojo rhyolite lava from the northern part of the dome, sample S7, showing glomeroporphyritic sanidine phenocrysts (S) in a felsitic groundmass partially recrystallised to mosaic quartz and K-feldspar (M), with some sodic amphibole microphenocrysts (white arrows) visible on the rim of the hole in the thin section to the right of the sanidine. Cross polarised light, field of view 2.5mm.

show flowbanding preserved by variations in grainsize of the felsitic textures or mosaic recrystallisation. Groundmass riebeckite microphenocrysts are often altered to amorphous brown material or opaque iron oxides. The common occurrence of felsitic groundmass quench textures indicates that these rocks were undercooled (Fig. 4.11B).

4.4.2 Pumice Flow Unit

The pumice flow sample is a crystal poor vitric tuff, consisting of irregular, partly flattened juvenile rhyolitoid lithic fragments and poorly vesicular pumice clasts in a grey felsitic matrix of devitrifed ash with traces of vitroclastic texture. Lithic fragments are sparse, but include oxidised fragments of silicic tuff, which could be derived from either the Ibáñez or Divisadero Formations. The matrix and pumices are stained brown by fine grained haematite, and vapour phase crystallisation of fine grained biotite appears to have taken place in some pumice vesicles. Pumices are faintly yellow in plane polarised light, and have devitrified into felsitic texture or a mosaic of quartz and K-feldspar, although microlites are still present. Mafic phases in the matrix have been altered to fine granular and acicular haematite and goethite, or to amorphous brown pleochroic material. However some pumices have slightly altered microphenocrysts that may be blue-green sodic amphibole.

Summary

Due to the ubiquitous felsitic or devitrified groundmass textures of these rocks, estimation of modal mineral proportions is not feasible, so normative QAP proportions are plotted from XRF data (see Chapter 5) for Cerro Pico Rojo obsidian, tuff and lavas are shown in Figure 4.12. These rocks are all rhyolitic lavas, and cluster clearly in the centre left of the rhyolite field, with two outliers, with the obsidian sample showing higher quartz content, and one altered lava sample from basal brecciated zones of Cerro Pico Rojo showing higher quartz and K-feldspar content. Their evolved nature is evident through their lack of more calcic plagioclase than occasional albite and the presence of sodic amphiboles as

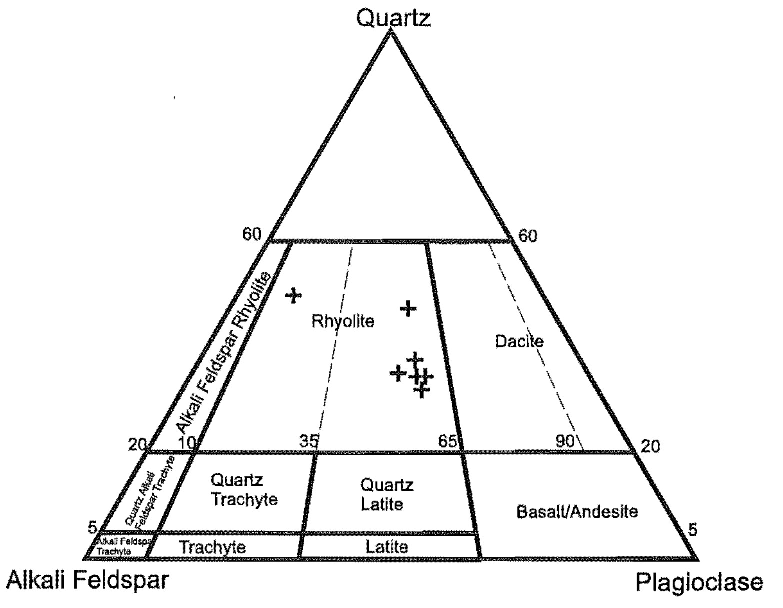


Figure 4.12: Normative QAPF plot for rhyolites from the Cerro Pico Rojo dome complex. Fields after Streckheisen (1979) (Data from normative compositions, see chapter 5).

a groundmass phase. These rocks show varying degrees of undercooling textures, with obsidian present at the dome margins, while the inner parts of the dome give samples with partially recrystallised felsitic textures and in one sample from the core of the dome at Cerro Pico Rojo there are remnants of spherulitic textures, although these are more evident in hand specimen than in thin section.

4.5 Plateau Basalts

Plateau basalt lavas outcrop to the northeast of Cerro Pico Rojo and overlie both the Divisadero Formation and the Cerro Pico Rojo Rhyolite. Three samples were cut for thin section. These rocks are from thick (150m) stacks of 1–10m pahoehoe and áa type lavas, and are also associated with small scoria cones and plugs.

The lavas are porphyritic, with phenocrysts of plagioclase, augite and occasional olivine altered to iddingsite, in a pilotaxitic (Fig. 4.13A) or intergranular (Fig. 4.13B) groundmass of plagioclase, magnetite and clinopyroxene. There are possibly some biotite microphenocrysts, and some anhedral K-feldspar interstitial to plagioclase and mafic microphenocrysts.

Plagioclase phenocrysts range from 0.5–4mm, whereas groundmass microphenocrysts are below 0.5mm in size. Altogether, plagioclase comprises between 45–70% of the samples. Phenocrysts are euhedral and subhedral, with sieve textures and oscillatory normal zoning from bytownite at cores to labradorite at rims. Groundmass plagioclase microphenocrysts range in composition from andesine to labradorite. Brown augite phenocrysts range from 0.4–2mm, whereas groundmass pyroxenes are fine granular microphenocrysts below 0.1mm. Augite phenocrysts are euhedral to subhedral, often rounded or twinned, and may be included within plagioclase phenocrysts. Alteration of augite to murky green chlorite and iron oxides is common, usually on rims or along fractures and cleavage, or replacing entire phenocrysts. Olivine phenocrysts are sparse, <2mm, subhedral embayed or corroded crystals with pervasive alteration to murky or fibrous biotite-like red and brown iddingsite. Biotite, if present, occurs as small pleochroic grains in the groundmass, but some of these grains may be fibrous iddingsite replacing olivine microphenocrysts, rather than biotite.

Summary

The plateau basalts plot in the basalt/andesite field on a QAPF diagram (Fig. 4.14), and from their mineralogy of moderately sodic to calcic plagioclase and augite, with minor altered olivine, are petrographically basalts to basaltic andesites.

4.6 Minor Intrusive Rocks

Minor Intrusive rocks are varied. Some form recognisable groups in the field in terms of composition and form. Others are of variable composition and show no distinct affiliations. These rocks will be described according to their composition, rather than by the formations in which they are hosted.

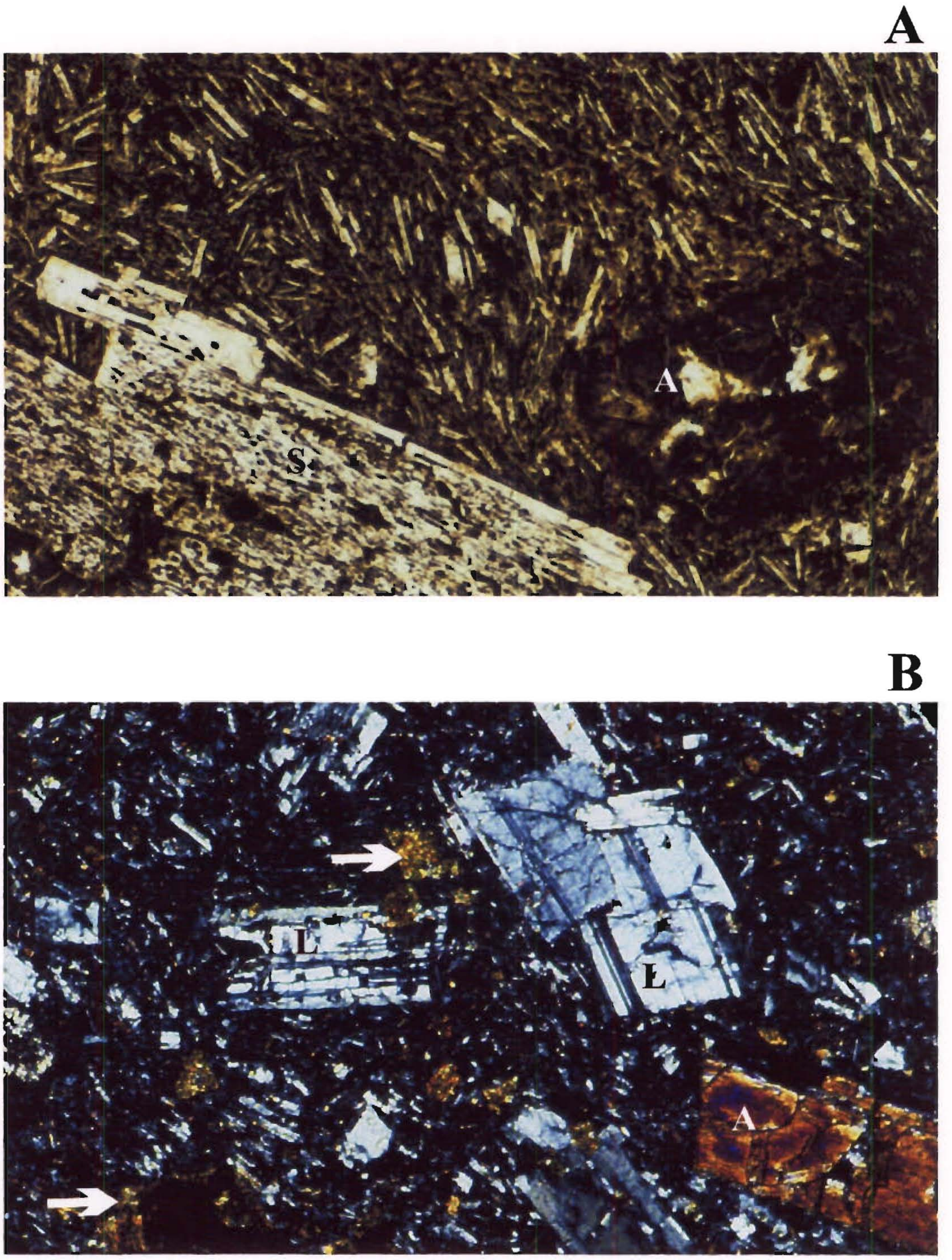


Figure 4.13: A) Photomicrograph of basaltic lava flow northeast of Cerro Pico Rojo, from sample S9A, showing phenocrysts of zoned (bytownite - labradorite) and sieve textured plagioclase (S), and green chloritised augite (A) in a groundmass of pilotaxitic labradorite microphenocrysts with intergranular magnetite and clinopyroxene. Plane polarised light, field of view 2.5mm. B) Photomicrograph of basaltic lava flow northeast of Cerro Pico Rojo, from sample S10, showing phenocrysts of labradorite (L) and augite (A), with brown pseudomorphs (white arrow) of an altered mafic mineral (either augite or olivine) within a groundmass of pilotaxitic sodic labradorite microphenocrysts with intergranular augite and magnetite.

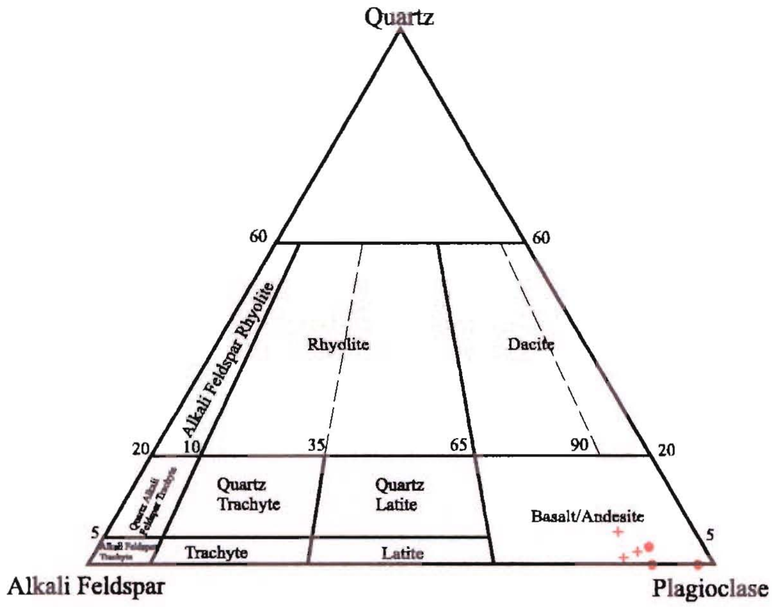


Figure 4.14: QAPF plot for three samples of the Plateau Basalts from northeast of Cerro Pico Rojo. Fields after Streckheisen (1979). Mineral proportions (red dots) are by visual estimation, crosses represent normative compositions (see chapter 5).

4.6.1 Undersaturated Basaltic Minor Intrusive Rocks

The most mafic minor intrusive rocks are a stock cutting the Apeleg Formation and Divisadero Formation at Estancia Moroma (GR 282860 4868900), and a sill emplaced in the Ibáñez Formation at the Peninsula Ibáñez (GR 288173 4869185). These rocks are the only samples which contain visible olivine phenocrysts in hand specimen. In thin section they have phenocrysts of light brown titanian augite, plagioclase, iddingsitised olivine, occasional dark brown hornblende, and rounded, altered nepheline in a groundmass of plagioclase microphenocrysts with integranular brown biotite, magnetite, altered brown glass and some interstitial alkalki feldspar.

Titanian augite phenocrysts range from 5–15%, and are euhedral to subhedral crystals from 0.5–3mm. There is some intergrowth with brown hornblende or alteration to fibrous green or brown uralite, or sometimes to platy chlorite and calcite. Olivine phenocrysts range from 3–8%, and are 5–15mm in hand specimen but are mostly only 1–3mm euhedral and subhedral corroded crystals in thin section. Most are altered to brown iddingsite or fibrous green bowlingite or chlorite/serpentinite, and some are replaced by calcite and secondary quartz. Plagioclase is confined to groundmass in the stock, forming 45% of the rock as <1mm subhedral and euhedral swallowtailed calcic labradorite. The sill is about 60% plagioclase with 10% of 1–3mm large sieve textured andesine phenocrysts and unusually, a finer groundmass of <0.5mm labradorite microphenocrysts. Both rocks contain rounded phenocrysts of <5% nepheline, often altered to analcime or wairakite, or to murky calcite. Analcime also occurs as a void filling with calcite. Red brown pleochroic hornblende, <1mm, <1%, possibly kaersutite, occurs in the sill on Peninsula Ibáñez, but not in the stock at Estancia Moroma.

Groundmass textures in these two rocks are similar. A framework texture of randomly oriented plagioclase microphenocrysts has intergranular magnetite, fine granular augite, fibrous or bladed aggregates of partially altered biotite and brown murky glass with opaque microlites, and some anhedral interstitial K-feldspar (Fig. 4.15B).

Summary

These two samples contain no primary quartz, but have traces of primary nepheline, so although they plot within the basalt/andesite field, they do so below the A-P line, and may be called mugearites (Fig. 4.15A).

4.6.2 Basaltic, Basaltic Andesitic, Trachybasaltic/Andesitic and Andesitic Minor Intrusive Rocks

Basaltic, basaltic andesitic, trachybasaltic/andesitic rocks, and andesitic intrusive rocks outcrop as small dikes, sills and stocks throughout the field area, and may cut any of the mapped units. All plot within the basalt/andesite field on a QAPF plot and the distinction between basaltic to andesitic and trachybasaltic to trachyandesitic rocks is based on the chemical analyses presented in Chapter 5, rather than by petrographic distinctions. In some cases, trachybasaltic to trachyandesitic chemistry may be due to mobility of the alkali elements rather than primary characteristics, particularly given the high LOI values of some of these samples. Twenty-two samples were cut from sills, dikes and

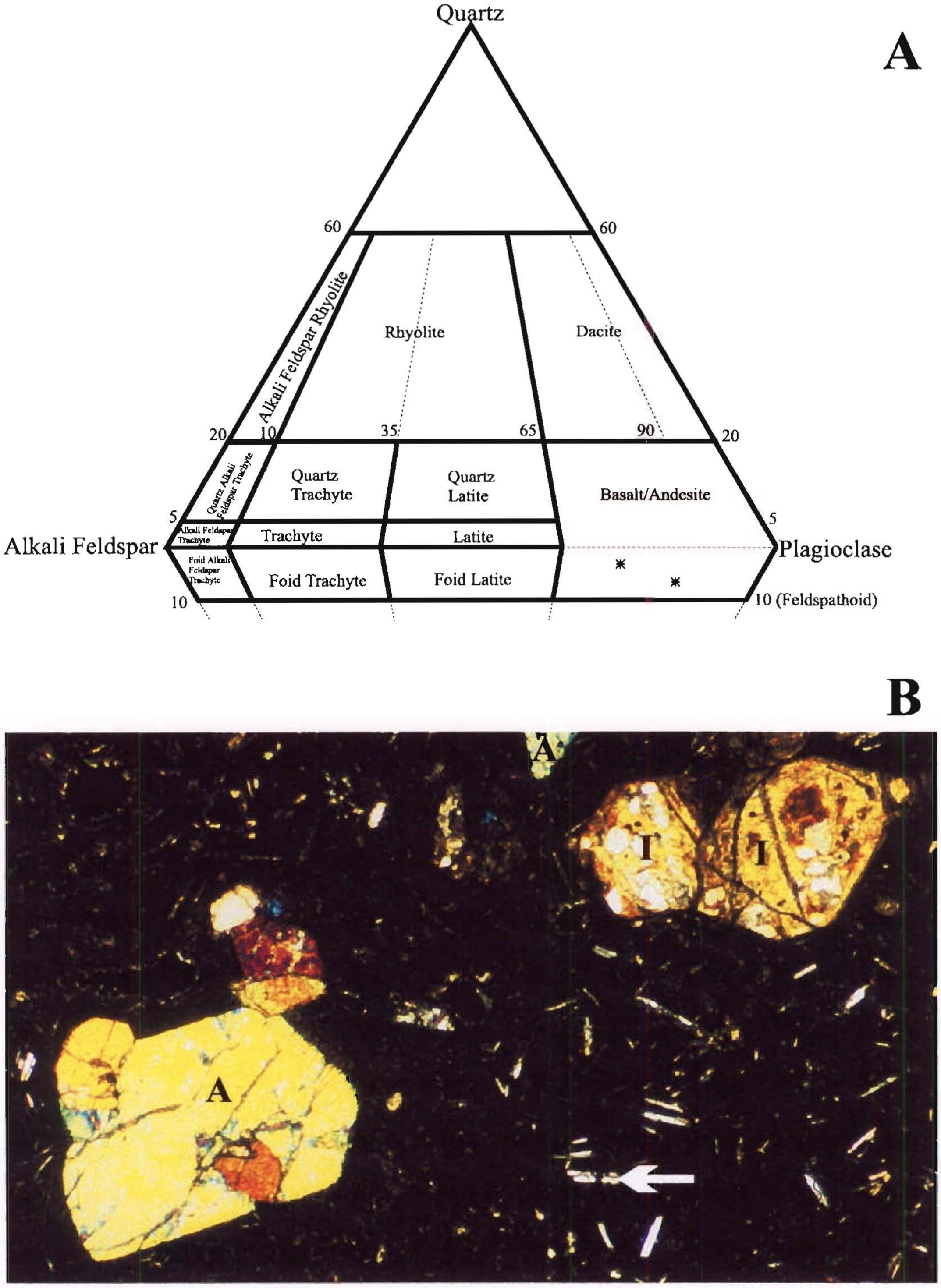


Figure 4.15: A) QAPF plot for nepheline bearing basaltic minor intrusive rocks cutting the Ibáñez and Divisadero Formations near Estancia Moroma and on the Peninsula Ibáñez. Mineral proportions by visual estimation except K-feldspar, which is extrapolated from normative compositions (see chapter 5). Fields after Streckheisen (1979). B) Photomicrograph of mugearitic basalt from west of Estancia Moroma, from sample F45, showing subhedral glomeroporphyritic titanian augite (A) and iddingsitised olivine phenocrysts (I), in a dark brown isotropic glass groundmass with intergranular calcic plagioclase (arrow), clinopyroxene, magnetite and occasional biotite.

stocks hosted within the Ibáñez Formation, Coyhaique Group and Divisadero Formation. These rocks are mainly comprised of phenocryst phases of plagioclase and clinopyroxene with lesser proportions of K-feldspar and magnetite, and may contain quartz, olivine, orthopyroxene, biotite, amphibole, and glass. Textures range from fine grained pilotaxitic aphanites through porphyritic volcanic textures, to granular medium grained hypabyssal microgranitic textures.

Plagioclase is the dominant phenocryst phase in these rocks, ranging from 48–80%, as either phenocrysts from 1–4mm or as groundmass microphenocrysts <1mm. Large phenocrysts may be euhedral, subhedral or occasionally anhedral (in microgranitic textured samples), and often show normal oscillatory zoning. They are glomeroporphyritic or show sieve textures, whereas groundmass plagioclase is usually subhedral or as euhedral laths with some swallowtail quench textures and pilotaxitic textures. Basaltic, basaltic-andesitic and basaltic trachyandesitic plagioclase ranges from bytownite to calcic labradorite and to calcic andesine in larger phenocrysts, and from sodic labradorite to calcic andesine or even oligoclase in the groundmass; altered examples have albitised plagioclase, oligoclase or albite. Andesitic and trachyandesitic plagioclase ranges from bytownite to andesine in larger phenocrysts, but often is in the form of phenocrysts of andesine with groundmass oligoclase and albite. Altered samples also show albitisation of plagioclase. In many cases alteration of plagioclase phenocrysts and microphenocrysts is especially prominent in the cores of zoned phenocrysts. Alteration products are calcite, sericite, chlorite, and epidote, or patchy K-feldspar.

Quartz ranges from 0–15%, usually as rare groundmass material, usually anhedral grains <0.5mm, interstitial to the other groundmass phases. Some glassy rocks have mosaic quartz formed by recrystallisation of groundmass material. Some quartz also occurs as secondary void fillings, accompanied by cristobalite or tridymite.

K-feldspar is difficult to identify in most samples, but may range from 2–20%. It is present only as fine grained, anhedral interstitial material in the groundmass or as alteration of plagioclase, again usually <0.5mm. K-feldspar may sometimes be present as mosaic recrystallisation material with quartz, or in fine grained granophyric intergrowth with interstitial quartz.

Mafic minerals may include augite, orthopyroxene, hornblende and olivine, although these minerals are often altered to chlorite, uralite, haematite, iddingsite and similar alteration products.

Augite is the most common mafic phase, and may comprise 2–20% of the rocks. In basaltic andesitic and andesitic rocks it is often accompanied by 2–8% orthopyroxene. Pyroxenes occur both as phenocrysts up to 2mm and as groundmass phases. Basaltic and basaltic andesitic rocks usually having slightly brown or 'flesh' toned augite, whereas more andesitic and trachyandesitic rocks contain colourless or slightly green augite. In many samples, particularly from the andesitic to trachyandesitic rocks, pyroxenes are altered to fibrous or amorphous green chlorite, and are only identified by their crystal habit.

Hornblende is present in one basaltic andesite and some basaltic trachyandesites and andesites, usually as a minor groundmass phase, although in a vent breccia cutting the Apeleg Formation at Estancia Moroma and a micrograniti textured andesitic stock from southwest of Puerto Rey, it is the dominant mafic phase. Groundmass hornblendes range from 0–12%, and are brown or green brown pleochroic varieties, usually <1mm and subhedral or anhedral. Where it is the dominant mafic phase as in the two samples (above) it occurs as phenocrysts of pleochroic green hornblende from 1–6mm. Hornblende is often altered to fibrous green tremolite-actinolite or chlorite, and in some samples, larger phenocrysts of hornblende have well developed reaction rims of opaque minerals and chlorite.

Olivine is present in only two samples, as 1–5% chloritised or iddingsitised subhedral or euhedral pseudomorphs, <2mm, in a basaltic andesitic stock and a basaltic trachyandesitic sill, both emplaced into or through the Divisadero Formation near Cerro Pico Rojo.

Textures encountered in basaltic, trachybasaltic/andesitic and andesitic minor intrusive rocks are generally volcanic, with most rocks being porphyritic with phenocrysts of plagioclase, pyroxene, olivine or hornblende in an intergranular or pilotaxitic groundmass of plagioclase feldspar and altered mafic microphenocrysts with minor amounts of interstitial quartz, glass or K-feldspar (Fig. 4.16A). Some rocks, usually dikes, are very fine grained and aphanitic, without the phenocryst phases and showing only the pilotaxitic groundmass textures, indicating retardation of crystal growth by quenching against the host rock. Thicker sills and stocks are more likely to show strongly porphyritic textures with large phenocrysts. One stock southwest of Puerto Rey (GR 271070 4859298), and some trachyandesitic/andesitic sills from Peninsula Ibáñez (GR 288123 4865027) have well developed microgranular textures (Fig. 4.16B). Those rocks showing volcanic textures indicate relatively shallow emplacement, whereas the coarser grained rocks indicate deeper, more hypabyssal conditions.

Summary

Overall, these basaltic minor intrusive rocks can be identified on a QAPF (Fig. 4.17) plot as basalts, basaltic andesites and andesites, with division between basaltic and basaltic andesitic/andesitic based on the presence of two pyroxenes (if unaltered) and more sodic plagioclase in andesitic samples. There is no easy petrographic way to identify the trachybasaltic rocks, except perhaps by their lack of porphyritic textures and common trachytic textures, and their mainly albite-oligoclase feldspar compositon, but it is significant that these rocks show the greatest alteration and their trachyandesitic/trachybasaltic chemistry may be due to element mobility and high LOI values (see Chapter 5). The occurrence of groundmass glass in several samples, particularly in the basaltic and basaltic andesitic sills and dikes emplaced within the Divisadero Formation is evidence of quenching and probable shallow subvolcanic intrusion depths.

4.6.3 Phonolitic Minor Intrusives

One phonolitic dike outcrops on the Peninsula Levicán, emplaced through lapilli tuffs of the Ibáñez Formation. This rock is porphyritic with glomeroporphyritic albite and K-feldspar phenocrysts and microphenocrysts in a poikilomosaic groundmass of K-feldspar, nepheline, and secondary zeolites surrounding feldspar microphenocrysts and granular

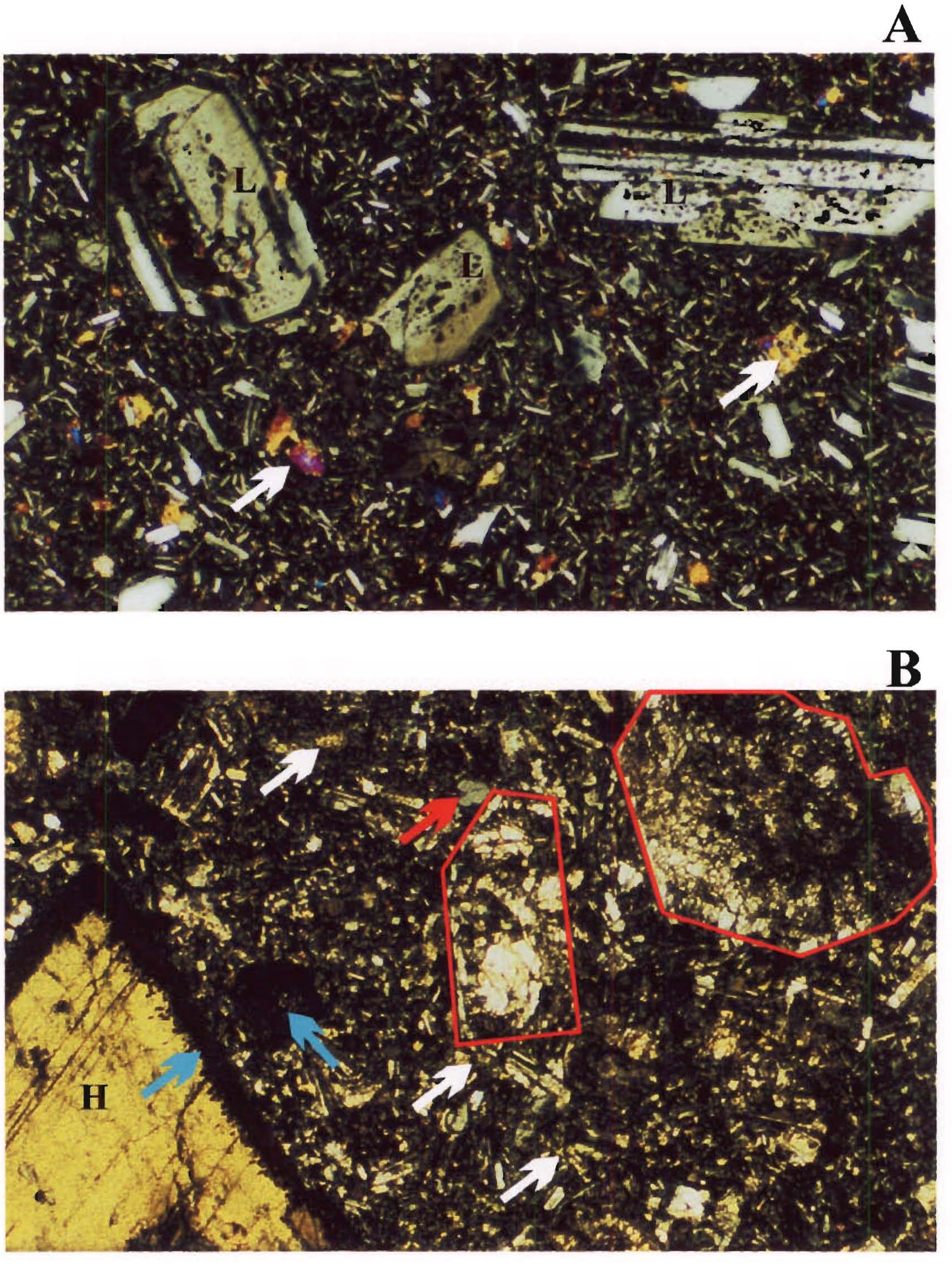


Figure 4.16: A) Photomicrograph of basaltic sill intruding the Divisadero Formation north of Cerro Cabeza Blanca, from sample F27B, showing sieve textured and normally zoned plagioclase (labradorite to oligoclase)(L), occasionally poikilitic around augite microphenocrysts, and a groundmass of intergranular plagioclase, augite (white arrows) and magnetite microphenocrysts with intersertal isotropic brown glass. Cross polarised light, field of view 5mm. B) Photomicrograph of andesitic stock cutting the Ibáñez Formation southwest of Puerto Rey, from sample WI30, showing large phenocrysts of green hornblende (H) with reaction rims of opaque minerals (Blue arrows), and altered phenocrysts of subhedral zoned plagioclase (bytownite to labradorite) (red outlines) which have been replaced by albite and K-feldspar. Groundmass is comprised of intergranular to microgranular plagioclase (albitised) with interstitial chlorite (after pyroxenes, white arrows), oxidised magnetite and anhedral interstitial quartz (red arrow). Cross polarised light, field of view 5mm.

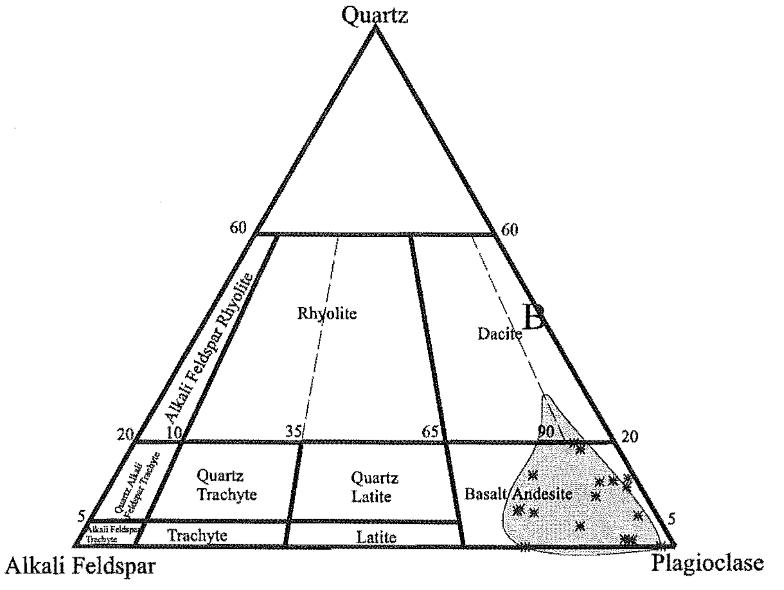


Figure 4.17: QAPF plot for basaltic and andesitic minor intrusive rocks, after Streckheisen (1979). Shaded field shows normative compositions for the same samples (see Chapter 5).

analcime, aegirine and green arfvedsonite.

Feldspar phenocrysts are euhedral, 0.5–3mm crystals, about 10%, often radially glomeroporphyritic, with some alteration to brownish sericite and clays, or replacement by mosaic K-spar, zeolite or nepheline. Phenocrysts have occasional remnant albite twins, particularly in microphenocrysts, but twinning is rare in larger phenocrysts. There are about 30% albite and 5–10% anorthoclase phenocrysts and microphenocrysts, and 20% mosaic K-spar in groundmass poikilomosaic material.

Groundmass has well developed poikilomosaic texture with feldspar microphenocrysts, both albite and anorthoclase, 10% green aegirine and about 2% green amphibole — probably arfvedsonite, surrounded by a mosaic of anhedral K-spar, zeolites after feldspar or nepheline, occasional unaltered nepheline, and some isotropic analcime (Fig. 4.18).

This rock plots on a QAPF diagram as a phonolitic tephrite, very close to the tephritic phonolite field (Fig. 4.19).

Figure 4.18: Photomicrograph of the phonolitic dike from Peninsula Levicán, sample L5α, showing pilotaxitic subhedral albite and anorthoclase K-feldspar microphenocrysts in poikilomosaic texture with groundmass K-feldspar and nepheline, and fine granular aegirine and sodic amphibole microphenocrysts (white arrows). Cross polarised light, field of view 2.5mm.

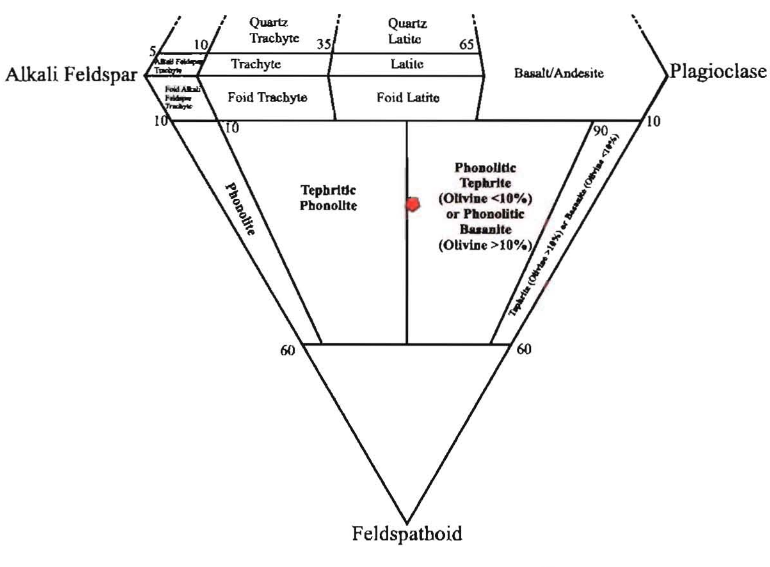


Figure 4.19: QAPF plot for nepheline bearing dike cutting the Ibáñez Formation on Peninsula Levicán, after Streckheisen (1979). Mineral proportions by visual estimation.

4.6.4 Dacitic and Rhyolitic Minor Intrusives

Dacitic, rhyodacitic and rhyolitic minor intrusive rocks occur throughout the field area as dikes, stocks and sills, some of which can be grouped on field characteristics. In particular, dacitic rocks cut the Ibáñez Formation, Coyhaique Group and Divisadero Formation as a series of stocks exposed on the the peninsula at La Pedregasa (GR 280230 4867400), and as dikes cutting the Coyhaique Group and Divisadero Formation further east on the lake shore southwest of Estancia Moroma (GR 280230 4867400). Also, small groups of minor volume dacitic dikes and stocks cut the Ibáñez Formation on the southwest slopes of Cerro Pirámide (GR 278335 4869433, 277735 4870270 and 277673 4870000). These dikes have distinctive orange weathering colours and large quartz phenocrysts and biotite. Other examples cut the Ibáñez Formation at Puerto Rey (Dacitic, GR 270507 4856660), Laguna La Pollolla (Rhyolitic, GR 289762 4869589 and 289954 4871335) and on the shore of the Bahia Ibáñez east of El Maiten (Rhyolitic, GR 270630 4863100 and 276460 4863460) show no particular hand specimen or field associations with each other. Eighteen samples were cut from these and other occurrences. Due to the prevalence of fine grained felsitic and quartz-feldspar mosaic groundmass textures, mineral estimation for groundmass minerals was extrapolated from normative compositions (see Chapter 5).

These rocks are porphyritic, with 10–50% phenocrysts, usually sodic plagioclase and sometimes quartz. Minor phenocryst phases may include hornblende, augite, orthopyroxene, biotite and magnetite, with traces of apatite and zircon. Most samples show slight to moderate alteration, particularly of feldspars and mafic phases, to sericite, calcite and K-feldspar and to chlorite, uralite, calcite, leucoxene, muscovite and haematite, respectively.

Plagioclase phenocrysts are present in all samples, and range from 5–40%. They are euhedral and subhedral 0.5–7mm crystals, often glomeroporphyritic, but with occasional simple zoning or sieve textures. Labradorite is rare, with most plagioclase ranging from sodic andesine down to albite. Zoned crystals may show labradorite cores to sodic andesine or albite rims, but most samples show unzoned or simply zoned plagioclase with andesine at cores and oligoclase or albite at rims. Many phenocrysts are albitised.

Quartz phenocrysts are rare in most of the dacitic and rhyolitic rocks, present as a major phenocryst phase in four dacitic dikes from Cerro Pirámide and two stocks at Lago La Pollolla. In most other samples it is present only as microphenocrysts or within groundmass felsitic material. Quartz phenocrysts range from 3–10%, usually as subhedral bipyramids, often rounded and embayed. In the rhyolitic stocks at Lago La Pollolla and the three dacitic dikes from Cerro Pirámide, the phenocrysts are large, embayed and elongate bipyramids up to 6mm in thin section and 10–12mm in hand specimen, whereas in most other samples quartz phenocrysts are either not present or are small microphenocrysts <1mm. Phenocrysts are often rounded, and in dacites from Cerro Pirámide and La Pedregasa have well developed fine overgrowths of mosaic material derived from groundmass mosaic quartz.

Mafic phenocryst phases are hornblende, pyroxene or biotite, and can be roughly grouped according to sample location. The two rhyolitic stocks at Laguna La Pollolla, a rhyolitic sill east of El Maitén, and four dacitic dikes from Cerro Pirámide contain biotite or biotite and hornblende, whereas the dacitic stocks and dikes from the peninsula at La Pedregasa and on the lakeshore southeast of Estancia Moroma contain altered pyroxene, often augite but sometimes orthopyroxene and occasional minor hornblende and biotite. In most samples, mafic minerals are partly or wholly altered to chlorite, uralite, or mixtures of chlorite-muscovite-leucoxene-calcite-haematite, and are hence unidentifiable, or only identifiable by the shape of pseudomorphs or by small unaltered remnants.

Identifiable brown-green euhedral hornblende is present in three samples, and ranges from 0.5–10%, usually 0.5–1mm phenocrysts, but occasionally up to 5–6mm. Most hornblende phenocrysts are identifiable only as pseudomorphs replaced by platy or fibrous chlorite and green actinolitic amphibole.

Biotite phenocrysts occur in 7 samples, ranging from 0.5–5%, in subhedral and euhedral booklets from 0.5–4mm. It forms either phenocrysts or interstitial material to other mafic and accessory minerals, often magnetite, apatite and zircon. Biotite phenocrysts in most samples are altered to green-brown chlorite, or replaced by muscovite interlayered with opaque leucoxene, goethite/haematite and calcite. Remnant unaltered phenocrysts in rhyolitic samples and some dacites are green-brown pleochroic biotite, with red-brown biotite occurring in only one dacitic sample from La Pedregasa.

Pyroxenes occur as phenocrysts in the dacitic stocks and dikes outcropping between La Pedregasa and Estancia Moroma. Phenocrysts range from 3–5%, are subhedral and euhedral, 0.5–3mm in size. They are usually altered to chlorite or uralite, or sometimes to calcite and haematite, and like hornblende, are often identifiable only by the shape of the pseudomorphs or by small remnant patches. Both colourless to pale green augite and colourless orthopyroxene occur, although both were not observed in the same samples. Orthopyroxene phenocrysts are associated with minor hornblende and biotite in one sample, and are partially altered to amorphous green chlorite (Fig. 4.20A). Augite is the only mafic phase present in most other samples from the Estancia Moroma group, although some samples with entirely altered mafics show both pyroxene and amphibole pseudomorphs.

Groundmass mineralogy in the dacitic samples consists of pilotaxitic sodic plagioclase microphenocrysts in either a matrix of felsitic material or interstitial quartz and K-feldspar, depending on the texture of the rock. Rhyolitic samples may have some sodic plagioclase in a poikilomosaic texture with recrystallised mosaic quartz and K-feldspar, or felsitic material with varying degrees of recrystallisation to mosaic textures (Fig. 4.20B). Minor accessory minerals in both dacitic and rhyolitic samples include magnetite and/or ilmenite, usually as 1–3% phenocrysts and microphenocrysts, up to 1–2mm but generally <1mm, and often associated with mafic phases, particularly biotite. There are also trace amounts of apatite, zircon, cristobalite, tridymite, biotite, and altered fine grained mafic minerals (usually chloritised). Alteration of groundmass material may include patches of sericite, calcite, epidote, chlorite, haematite and clay.

The common occurrence of felsitic groundmass quench textures shows that these rocks are relatively shallow subvolcanic intrusions. Some rocks from the La Pedregasa-Estancia

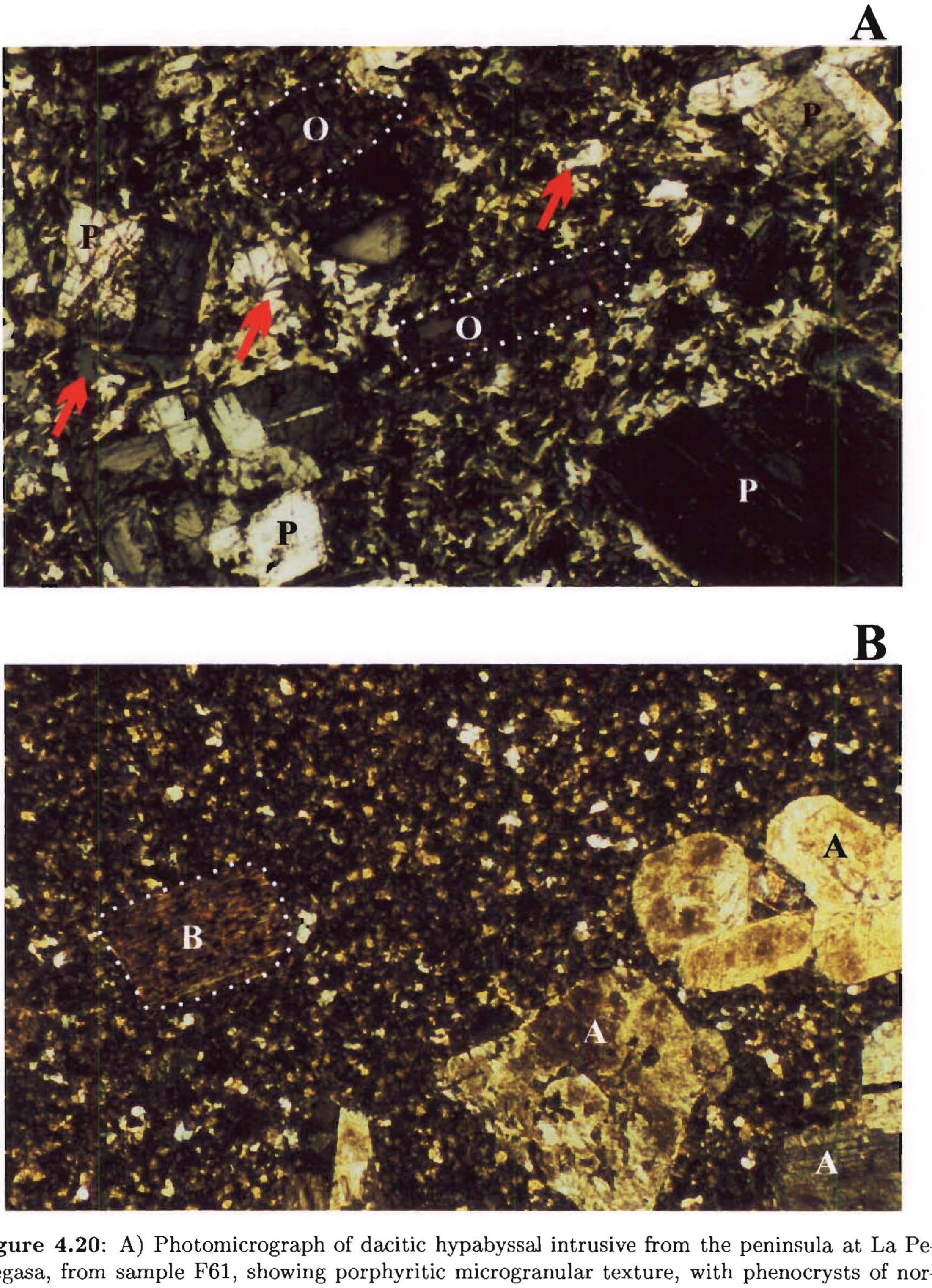


Figure 4.20: A) Photomicrograph of dacitic hypabyssal intrusive from the peninsula at La Pedregasa, from sample F61, showing porphyritic microgranular texture, with phenocrysts of normally zoned plagioclase (labradorite to oligoclase and albite) (P) and partially chloritised orthopyroxene (O, with dotted outlines)in a microgranular groundmass of subhedral albite, interstitial anhedral quartz (red arrows) and some biotite and magnetite (opaque or extinct in this view). Cross polarised light, field of view 5mm. B) Photomicrograph of rhyolitic minor intrusive from south of Cerro Cabeza Blanca, from sample F12, with phenocrysts of partly sericitised, murky glomeroporphyritic albite (A) and green brown euhedral biotite (B, dotted outline) in a groundmass of partly recrystallised brown felsitic quartz-K-feldspar mosaic.

Moroma dacites, although often porphyritic with felsitic or pilotaxitic groundmass quench textures, may also have coarser mosaic and microgranitic groundmass textures, comprised of microgranitic sodic plagioclase and altered mafics with patchy mosaics of interstitial granophyric quartz and K-feldspar. This texture indicates slightly deeper levels of intrusion, and although still under hypersolvus crystallisation conditions (Fig. 4.21A).

Summary

Although some samples are chemically trachytic or rhyolitic, most are dacites, and samples plot on a QAPF diagram as dacites to rhyodacites and some quartz-rich andesites. (Fig.4.21B). The La Pedregasa-Estancia Moroma dacites, and to a lesser extent, the three dacitic dikes from Southwest Cerro Pirámide are readily identifiable as related groups of rocks by their similar mineralogies and textures. These rocks show either porphyritic volcanic textures with phenocrysts in a felsitic or mosaic quartz-feldspar matrix, or porphyritic microgranitic textures with interstitial granophyric intergrowths, both showing evidence of quenching and hypersolvus crystallisation conditions.

4.7 Granitoids and Microgranitoids

Granitoids and microgranitoids form the bulk of the Cerro Pirámide stock and underly much of Cerro Farellón. They intrude all mapped formations except the Cerro Pico Rojo Rhyolites and the Plateau Basalts. They also occur as isolated stocks and sills at Puerto Ibáñez, La Masira, El Maitén, Puerto Rey and southwest of Cerro Pirámide. Fifty-two samples were cut, mainly from the Cerro Farellón and Cerro Pirámide complexes, but also from microgranitoid stocks and sills from Puerto Ibáñez, West Ibáñez (El Maitén and Puerto Rey), southwest Cerro Pirámide. Four samples from the Patagonian Batholith, two each at Lago Bertrand and at Lago Esmeralda respectively were taken for Ar-Ar dating and comparison with the Ibáñez Quadrangle granitoids.

The rocks are all relatively leucocratic granitoids, with typical medium and coarse grained granitic textures and microgranitoids, showing a gradation from granitic to por-

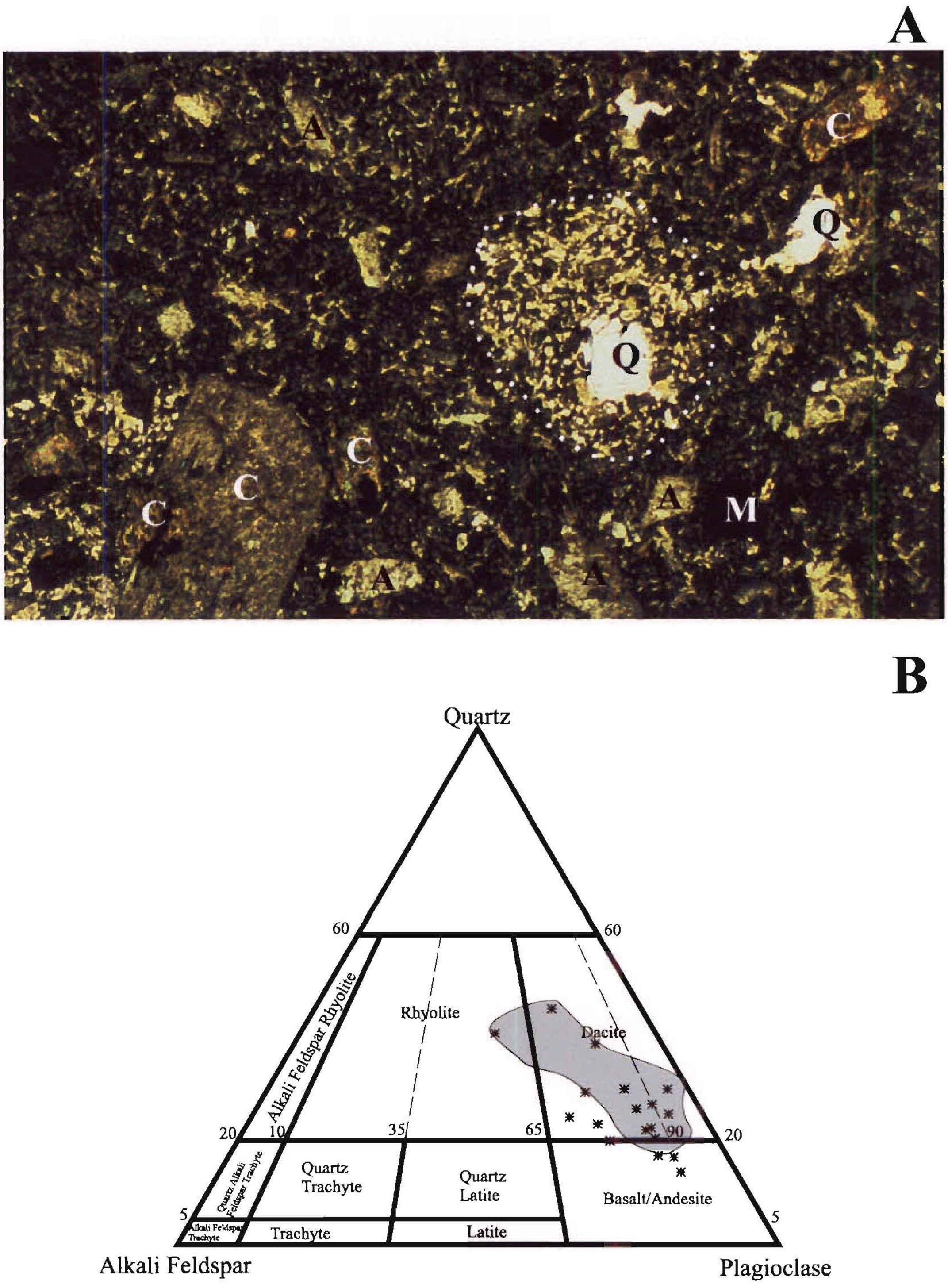


Figure 4.21: A) Photomicrograph of hypabyssal dacitic intrusive from Estancia Moroma, from sample F40, showing phenocrysts of clinopyroxene (C) replaced by chlorite and calcite, rounded andesine (A) and subhedral quartz (Q) in a microgranular groundmass of subhedral sodic plagioclase, chloritised mafics (usually biotite and pyroxene) magnetite (M) and clots of poorly developed quartz-K-feldspar granophyric intergrowth around quartz phenocrysts (dotted outline). Cross polarised light, field of view 5mm. B) QAPF plot showing dacitic and rhyolitic minor intrusive rocks emplaced in the Ibáñez Formation, Coyhaique Group and Divisadero Formation. Fields after Streckheisen (1979), data from visual estimation and extrapolation from normative compositions to estimate groundmass composition (Shaded field is normative only data (see Chapter 5)).

phyritic volcanic textures. Both groups contain major mineral phases of plagioclase and quartz with some K-feldspar, usually interstitial, and mafic and opaque phases of hornblende, biotite and magnetite. Trace minerals include titanite, apatite, zircon, ilmenite and epidote, whereas common alteration products of the major phases include sericite, chlorite, uralite calcite and epidote.

Plagioclase is present in all the granitoids and microgranitoids sampled, ranging from 40–75%, with an average of 58%, and is present as euhedral and subhedral crystals ranging from 0.1–6mm, but generally between 0.1–3mm, in hypidiomorphic textures with interstitial quartz, K-feldspar and mafic minerals. This is especially in samples from the Batholith (Lago Bertrand, Lago Esmeralda) and from the cores of the stocks at Cerro Pirámide and Cerro Farellón. Samples from the margins of the larger intrusive bodies, or from smaller sills and stocks have euhedral and subhedral plagioclase phenocrysts, sometimes glomeroporphyritic, in a microgranitic granular or coarsely felsitic groundmass of smaller plagioclase, mafic minerals and granular mosaic quartz and K-feldspar. Plagioclase is rarely sieve textured, but often zoned, usually as normal oscillatory zoning from labradorite or andesine in the cores to andesine or oligoclase and sometimes albite at rims, although some samples are zoned from cores as calcic as bytownite. In some cases zoned plagioclase may be overgrown with an outer rim of K-feldspar, or have a granular rim or framework of smaller groundmass crystals nucleated upon the outer rim of the plagioclase (Fig. 4.22A). Alteration is common, with most samples showing replacement of plagioclase by calcite or partial to complete sericitisation, in particular of the more calcic core zones. Many samples, particularly those from small microgranitoid dikes and sills around Cerro Pirámide, show varying degrees of saussuritisation of plagioclase, with partial or complete replacement by epidote, albite, calcite and sericite. This may be interpreted as hydrothermal alteration associated with the intrusion and cooling of the Cerro Pirámide stock.

Quartz may be present as the most common mineral after plagioclase, although it is sometimes only a minor component. It ranges from 4–30%, with a mean of 18%. In

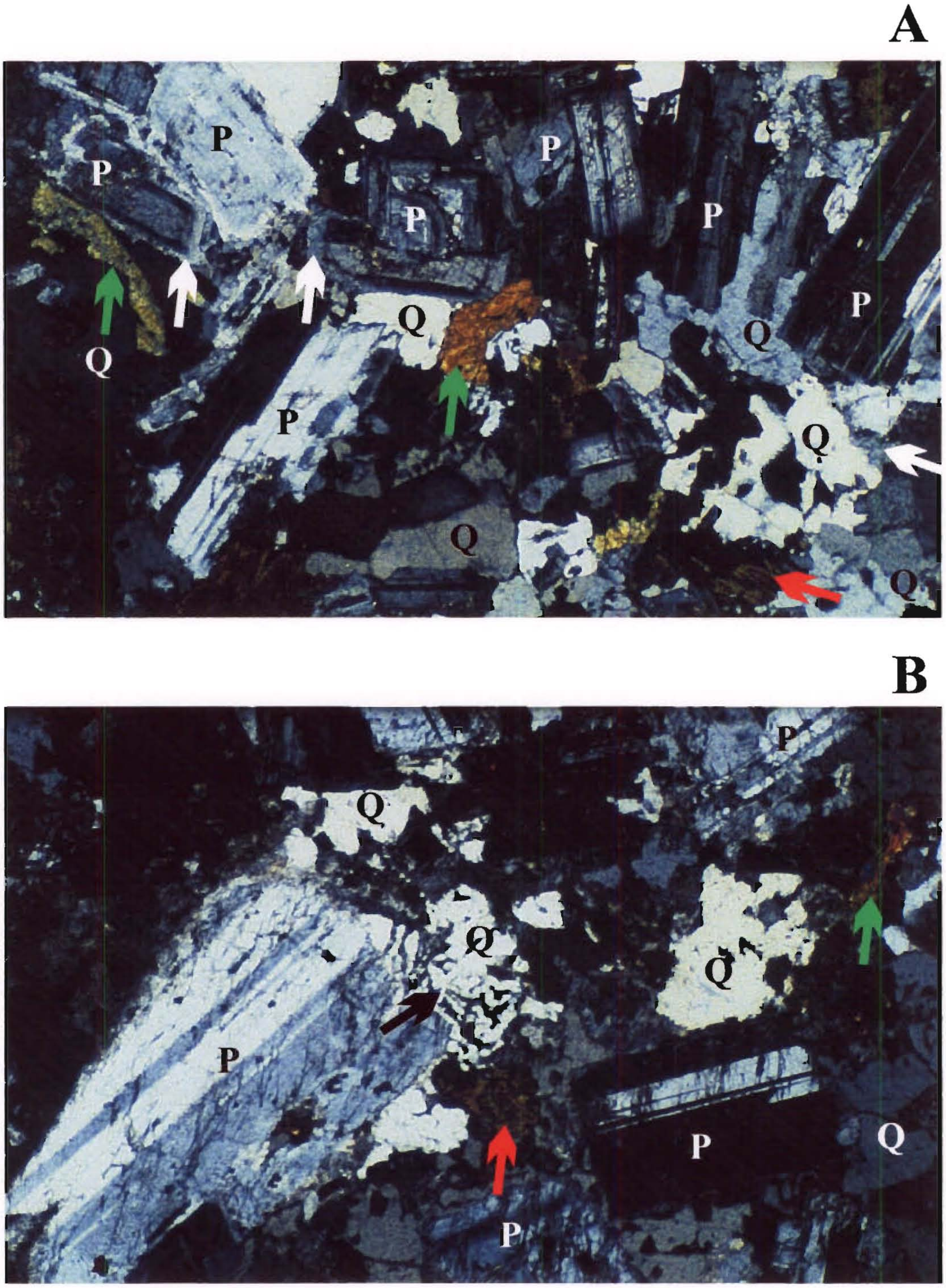


Figure 4.22: A) Photomicrograph of granodioritic rock from the lower parts of the Cerro Farellón Complex, from sample CF15, showing granitic texture dominated by subhedral and euhedral normally zoned plagioclase (andesine-oligoclase) (P) with interstitial anhedral quartz (Q), K-feldspar as rims over plagioclase and as anhedral grains with the quartz (white arrows), chloritised biotite (red arrow) and hornblende (green arrow). Cross polarised light, field of view 5mm. B) Photomicrograph of granodioritic rock from near the top of the Cerro Farellón complex, from sample CF41 C, with coarsely porphyritic granitic texture of oscillatory zoned andesine-oligoclase (P), in a matrix of interstitial quartz (Q), granophyric quartz-K-feldspar intergrowth (black arrow), hornblende (green arrow) and chloritised biotite (red arrow). Cross polarised light, field of view 5mm.

granitic and microgranitic textured rocks, quartz is usually present as anhedral crystals interstitial to the plagioclase and mafic phases, often in varying degrees of granophyric intergrowth with some K-feldspar. In the more porphyritic microgranitoids quartz may occur both as corroded, embayed or rounded subhedral paramorphs of beta quartz bipyramids and as anhedral granular mosaic material in the groundmass with plagioclase microphenocrysts and anhedral K-feldspar. Anhedral crystals in granitic samples from Lago Bertrand and Lago Esmeralda are large, 1–4mm grains, either enclosing or interstitial to subhedral or euhedral plagioclase. At Lago Esmeralda the quartz has granophyric rims. Anhedral quartz crystals in samples from the Ibáñez Quadrangle granitoids and microgranitoids are smaller, from 0.1–1mm, and are usually interstitial to plagioclase and mafic phases. They often show granophyric intergrowth with interstitial K-feldspar, particularly around the rims of quartz crystals, with granophyric textures usually more pronounced in samples from the roof and sides of the Cerro Farellón complex in particular. Porphyritic microgranitoids have quartz phenocrysts from 0.5–4mm, with granular groundmass quartz usually <0.5mm. Phenocryst quartz in the porphyritic microgranitoids often has fine grained epitaxial overgrowth of granular or mosaic quartz from the groundmass.

K-feldspar, usually orthoclase, is present in most samples as a minor component, ranging from trace to 20%, with an average of 9%. Crystals are usually small, <1mm, anhedral or mosaic interstitial groundmass material, often in granophyric intergrowth with quartz. Many samples with zoned plagioclase crystals include some plagioclase with partial or complete rims of K-feldspar over an outer zone of sodic plagioclase. Perthitic K-feldspar was not often observed, being present only in the sample from Lago Bertrand, but a few samples from the Ibáñez Quadrangle show subhedral small crystals of carlsbad twinned orthoclase. Overall, orthoclase occurs as rims on plagioclase and as interstitial anhedral crystals, often granophyric, in granitic textured samples, or as fine anhedral granular or mosaic groundmass material with quartz in the porphyritic microgranitoids. Only the coarse grained rock sampled from Lago Bertrand for Ar-Ar dating showed two feldspars as a major crystal phase, whereas the remaining samples from Lago Esmeralda and the Ibáñez Quadrangle have an early euhedral-subhedral plagioclase phase and late stage interstitial K-spar, often granophyric.

Mafic phases are brown or green-brown hornblende and green-brown biotite, often occurring in association with magnetite. In many samples containing one or both of these minerals, the mafic phases may be entirely altered to chlorite or fibrous actinolite, leaving them identifiable only by the shape of any pseudomorphs present, with hornblendes the most readily identifiable by this method.

Hornblende occurs in many samples as the main mafic phase, ranging from 1–15%, with an average of 6%. In granitic and microgranitic rocks it occurs as large (1–6mm) subhedral green to green-brown pleochroic crystals in granitic texture with other minerals, or as a smaller (0.5–3mm) interstitial phase in plagioclase rich rocks, and may form granular or radial interstitial aggregates with biotite, magnetite and apatite. The porphyritic microgranitoids may contain euhedral and subhedral green hornblende as a phenocryst phase, 1–6mm, and also as fine grained subhedral material in the granular or mosaic groundmass of these rocks. In the porphyritic microgranitoids, particularly from Cerro Pirámide, green hornblendes show reaction rims crowded with fine granular opaque minerals. In all samples hornblende is often partly or wholly altered, and may be replaced by fibrous green actinolite, or matted fibrous or amorphous green chlorite, and in some samples by calcite or epidote.

Biotite is green-brown pleochroic, and may occur in association with hornblende, or as the main mafic phase, ranging from 1–8%, with an average of 3%. Crystals are rarely euhedral, but usually subhedral and anhedral interstitial clusters or aggregates of mica booklets, usually <1mm. In some cases euhedral and subhedral crystals up to 2mm occur. Biotite often forms interstitial granular aggregates with hornblende, and is often accompanied by magnetite, titanite, and apatite, and may include some zircon crystals. Most samples show partial to complete alteration of biotite, usually by replacement with chlorite, but sometimes also with chlorite/epidote mixtures, in those samples which show strong albitisation and saussuritic alteration of plagioclase.

Trace minerals present in these rocks include magnetite as the opaque phase, along with titanite, apatite, zircon and sometimes primary epidote, whereas alteration products may include albite, K-feldspar, epidote, chlorite, uralite, sericite, leucoxene, haematite, pyrite and calcite.

Granitoids and microgranitoids from the Ibáñez Quadrangle are exclusively 'I' types, and grade between two textural types: A) A medium grained granitic textured rock with a single euhedral to subhedral zoned plagioclase phase, interstitial quartz (often slightly granophyric with K-feldspar), mafics (green-brown hornblende and/or biotite, often chloritised) and trace minerals (Fig. 4.22B); and: B) a finer grained porphyritic rock with phenocrysts of large (up to 6–7mm) plagioclase, corroded quartz and green-brown hornblende, in a granular to microgranular or mosaic groundmass of quartz, plagioclase microphenocrysts, some K-feldspar, mafic phases and trace minerals (Fig. 4.23A).

Both textural types show evidence of the high level, hypabyssal nature of the intrusions, and the textural types are clearly related to the size and type of the intrusive bodies mapped in the field. Coarser grained granitic rocks with little or no granophyric intergrowth are from the core of the largest parts of the Cerro Farellón complex south of Arroyo Rocoso, whereas medium grained granitic rocks with more noticeable interstitial granophyric intergrowth are from either the roof areas of the Cerro Farellón complex, from the sides of the stocks of Cerro Pirámide, or from some of the smaller stocks at southwest of Cerro Pirámide or at El Maitén. The microgranitoids with strongly porphyritic textures and fine, granular groundmass quartz/feldspar mosaics also tend to occur at the rims or roof of the Cerro Pirámide stock and Cerro Farellón complex or in the smaller stocks and dikes, particularly the Puerto Ibáñez microgranitoids exposed in the road above Puerto Ibáñez itself. The occurrence of single plagioclase feldspar phases as large euhedral and subhedral crystals with interstitial granophyric quartz-K-feldspar textures indicates that these rocks are relatively high level intrusions crystallising under initial subsolvus conditions with late stage 'freezing' producing eutectic/cotectic crystallisation of the interstitial

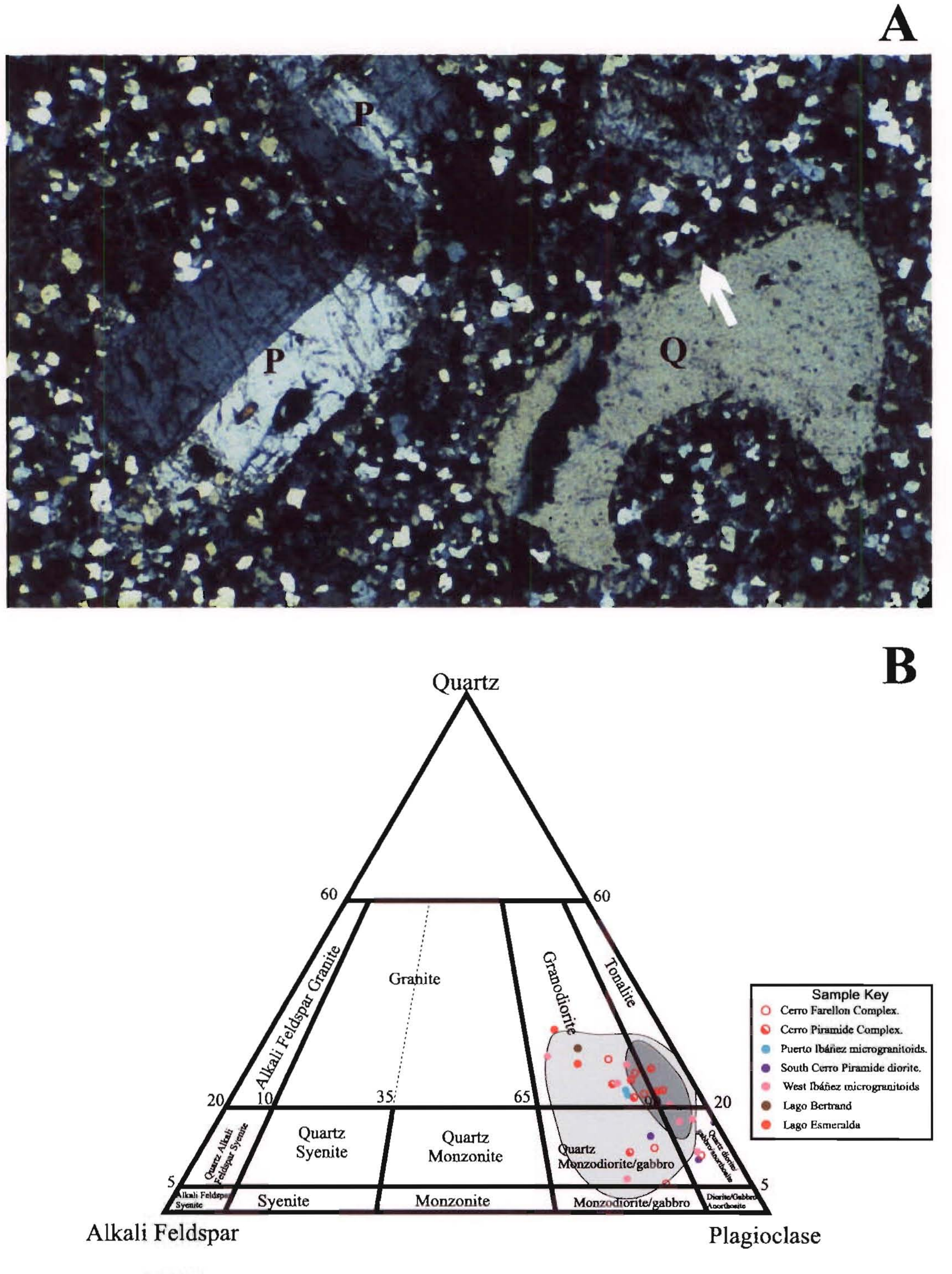


Figure 4.23: A) Photomicrograph of granodioritic rock from the northern margin of the Cerro Farellón complex, from sample CF27, coarsely porphyritic with phenocrysts of quartz (Q) and euhedral andesine (P), in a microgranular matrix of quartz, plagioclase and K-feldspar. Note skeletal overgrowth of matrix quartz around phenocryst quartz (white arrow). Cross polarised light, field of view 5mm. B) QAPF plot for granitic and dioritic rocks from the Ibáñez Quadrangle, southern Cerro Farellón Quadrangle and three samples of the Patagonian Batholith from Lago Bertrand and Lago Esmeralda. Fields after Streckheisen (1979). Shaded field shows range of normative compositions (see Chapter 5).

granophyric textures. The field evidence of sharp, fractured contacts with the country rocks, faulting and brecciation of the roof of the intrusion and the presence of miarolitic or 'drusy' cavities in the upper parts of the granitoid intruding Cerro Farellón may be taken as evidence that at least the Cerro Farellón granitoid was de-gassing, which can produce the conditions needed for crystallisation of granophyric intergrowths. The finer grained porphyritic textured microgranitoids, as they occur in particular near the rims of the larger intrusive bodies, or as smaller dikes and stocks (most are <500m in diameter, often <100m) may be interpreted as quench textures, also indicating relatively high level intrusion into 'cold' country rocks (note that the Patagonian Batholith dating samples from Lago Bertrand show coarse grained, two-feldspar granitic textures with plagioclase and perthitic K-feldspar and are without granophyric intergrowth, thus indicating sub-solvus crystallization, whereas the Lago Esmeralda samples show medium grained single (plagioclase) feldspar textures with interstitial granophyric intergrowth, similar to rocks from the Ibáñez Quadrangle, indicating a similar late stage 'freezing' event producing interstitial eutectic crystallisation).

Summary

The microgranitoids of the Ibáñez Quadrangle plot on the QAPF diagram of Le Maitre (1989) as quartz diorites, quartz monzodiorites, tonalites and granodiorites (Fig. 4.23B). They show mineralogies typical of 'I' type rocks (White and Chappell, 1977) and textures indicating crystallisation at high levels in the crust as subvolcanic stocks, dikes and sills, which matches well with their observed field occurrence and outcrop style. Many samples show evidence of alteration, with sericitisation and saussuritisation of plagioclase feldspar being particularly common, along with replacement of mafic phases by chlorite, epidote and calcite. This alteration is widespread, but is particularly common in samples within several kilometres of the major stocks at Cerro Pirámide and Cerro Farellón and in the marginal zones of these stocks themselves. It is likely to be related to the thermal effects of these large intrusions and deuteric alteration and hydrothermal systems associated with their emplacement and cooling.

Chapter 5

Geochemistry of the Ibáñez Area

5.1 Introduction

Geochemical analysis was carried out by XRF spectrometry. Major elements were analysed from borate glass fusion beads after the methods of Norrish and Hutton (1969), using both the older furnace and hand-pressed bead method and, later, larger beads from the automated Fusilux process. Trace elements were analysed via crushed and ground samples compressed into pellets. Results are contained in Appendix B. Numerical ranges given in the text are raw data including LOI, but all graphs are plotted LOI free, with major element data recalculated to LOI-free status using MS Excel and plotted with Newpet. All plots with samples which have LOI values greater than 3% have those samples plotted in a conflicting colour (orange) or are noted as having high LOI in the sample captions, indicating their high level of alteration. Trace element spider plots were normalised to the primitive mantle values of McDonough et al. (1992), as summarised by Rollinson (1993). These values were used mainly due to their wider element range than other normalisation values summarised by Rollinson (1993).

5.2 Ibáñez Formation

Forty-four samples of volcanic rocks from the Ibáñez Formation were analysed, from twenty rhyolitic tuffs and ignimbrites, nine rhyolitic lavas and domes, four dacitic lavas or domes and eleven andesitic lavas. These rocks plot on the TAS classification diagram of Le Maitre (1989) as basalts, basaltic andesites, dacites and rhyolites, with a calc-alkaline trend (Fig. 5.1A and 5.2.) Some samples plot as outliers above this trend, in the trachybasaltic through to trachyte fields, but these rocks either have high LOI, or from their field occurrence they can be interpreted as weathered or contact metamorphosed examples of the rocks which plot on the main trend. The samples plotting in the trachybasaltic to trachytic fields may have undergone some degree of Na–metasomatism, given the common occurrence of albitised plagioclase in Ibáñez rocks. The basalts and basaltic andesites are metaluminous, as are the dacites, whereas the rhyolites range from metaluminous to strongly peraluminous (Fig. 5.1).

5.2.1 Major Elements

Harker plots of Na_2O, K_2O, CaO and TiO_2 for the Ibáñez Formation are shown in Fig. 5.3. Those rocks from the most altered outcrops plot off the main chemical trends, indicating some element mobility due to weathering or the thermal effects of adjacent granitoid stocks. Harker plots of Al_2O_3, MnO, MgO and Fe_2O_3 show less scatter and hence more easily identifiable trends (Fig.5.4).

Basic rocks are basalts and basaltic andesites, in the range 45–58% SiO_2, and range from low to high K_2O from the basalts to basaltic andesites, although high K_2O samples are the most altered rocks. Petrographic olivine basalts are quartz-hypersthene normative, with only one sample showing normative olivine, while three of the petrographical basaltic andesite lavas contain normative olivine and/or nepheline.

Silicic rocks are quartz and quartz-hypersthene normative dacites to rhyolites, with 59.9–66.8% SiO_2 in dacites and 67.3–78.5% in rhyolites, with secondarily silicified samples as high as 85%. CaO is low, except for enrichment in altered samples, whereas K_2O and Na_2O are medium to high, although some samples have mobility of these elements due to weathering and contact metamorphism.

The Ibáñez Formation samples show strong decrease in CaO with increasing SiO_2 and initial enrichment of Na_2O in the basaltic and andesitic samples, followed by decreasing Na_2O trends in the more silicic dacitic and rhyolitic rocks. K_2O increases steadily with SiO_2, while TiO_2 is initially low and decreases with increasing SiO_2 content. Al_2O_3

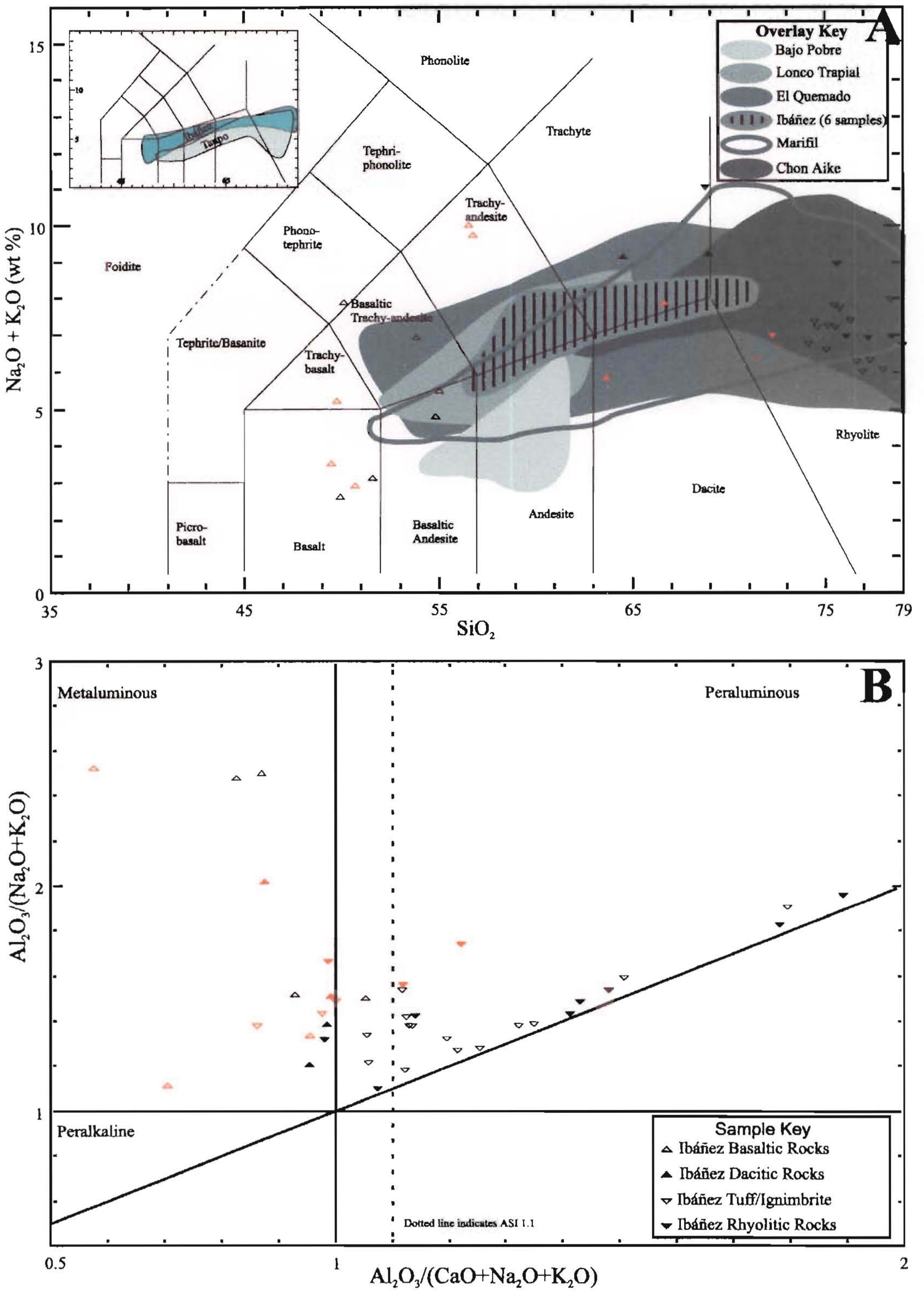


Figure 5.1: A) TAS plot for volcanic rocks of the Ibáñez Formation, after Le Maitre (1989). The Ibáñez Formation is a bimodal calc-alkaline association, which closely overlaps the fields of other major Jurassic volcanic provinces from Patagonia. Data for overlay fields is from Pankhurst et al. (1998). Note that the field for Ibáñez Formation data from Pankhurst et al. (1998) comprises only six samples from Baker et al. (1981). Points plotted in orange are from samples with LOI greater than 3%. The inset in top left corner compares the Ibáñez Formation with rocks from Taupo Volcanic Zone, NZ. (Data from Burt (1999).) B)ASI plot for volcanic rocks of the Ibáñez Formation, after Maniar and Piccoli (1989).

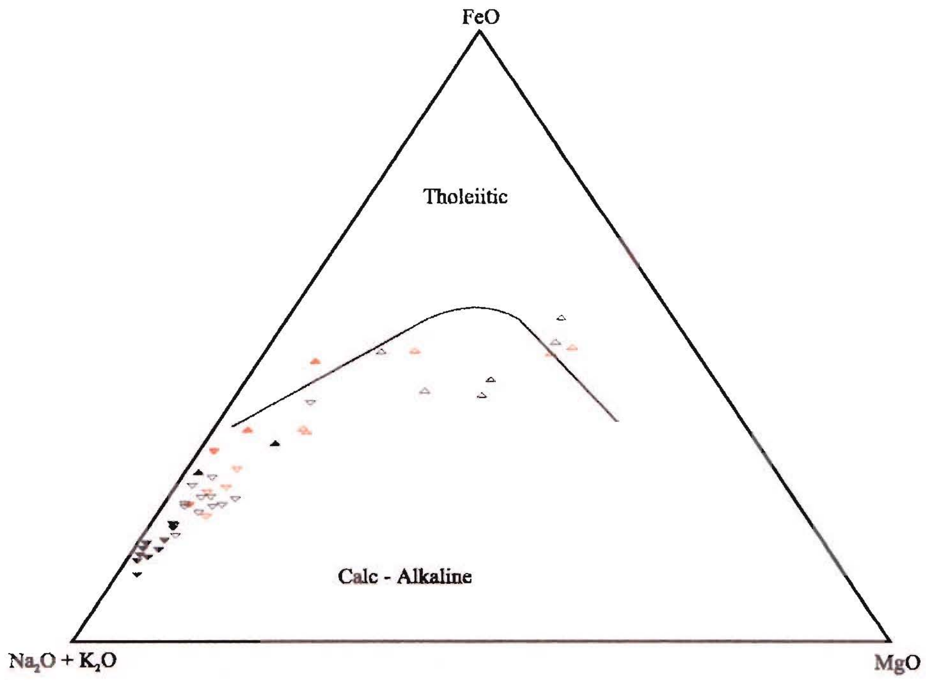


Figure 5.2: AFM plot for volcanic rocks of the Ibáñez Formation, after Irvine and Barragar (1971). Sample symbols as in 5.1, Points plotted in orange are from altered samples with LOI greater than 3%.

initially increases with SiO_2 in basaltic and andesitic samples and decreases in the silicic samples. MnO is initially low and decreases steadily with increasing SiO_2 content, while MgO is initially high and shows a marked decrease in the basic samples and then decreases, with shallower gradient in the more silicic samples. In several of the Harker plots for the Ibáñez Formation, particularly in plots of CaO, Al_2O_3, Na_2O, and MgO, there is a distinct change in gradient of the sample trends between the basic and acidic samples, indicating a compositional gap. The effects of weathering and low-grade metamorphism are evident on the major element plots (see Fig. 5.3), with depletion of CaO in altered or weathered basaltic to dacitic samples, whereas some basaltic samples have mild enrichment of K_2O. No distinct alteration trend is visible in the Na_2O and TiO_2 plots, although there is some scatter of data points. Al_2O_3, Fe_2O_3, MnO and MgO show less scatter of data, indicating lesser degrees of element mobility.

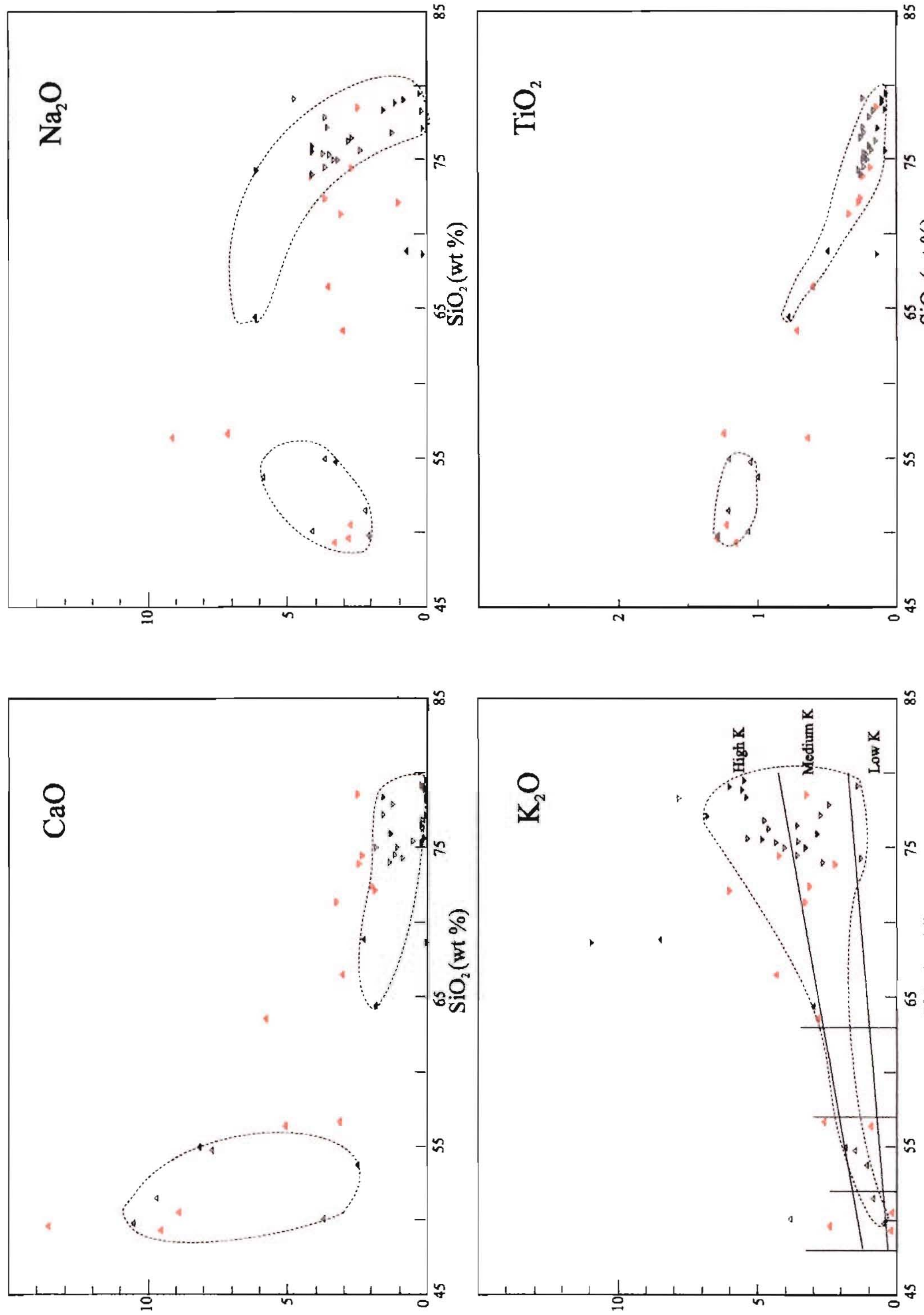


Figure 5.3: Harker variation diagrams for the alkali elements and TiO_2 from basaltic andesitic to rhyolitic rocks of the Ibáñez Formation. Samples with LOI greater than 3% are plotted in orange. Plot symbols are as in previous figures and dashed lines indicate main trends. Fields on K_2O-SiO_2 diagram are after Le Maitre (1989).All data plotted as Wt%.

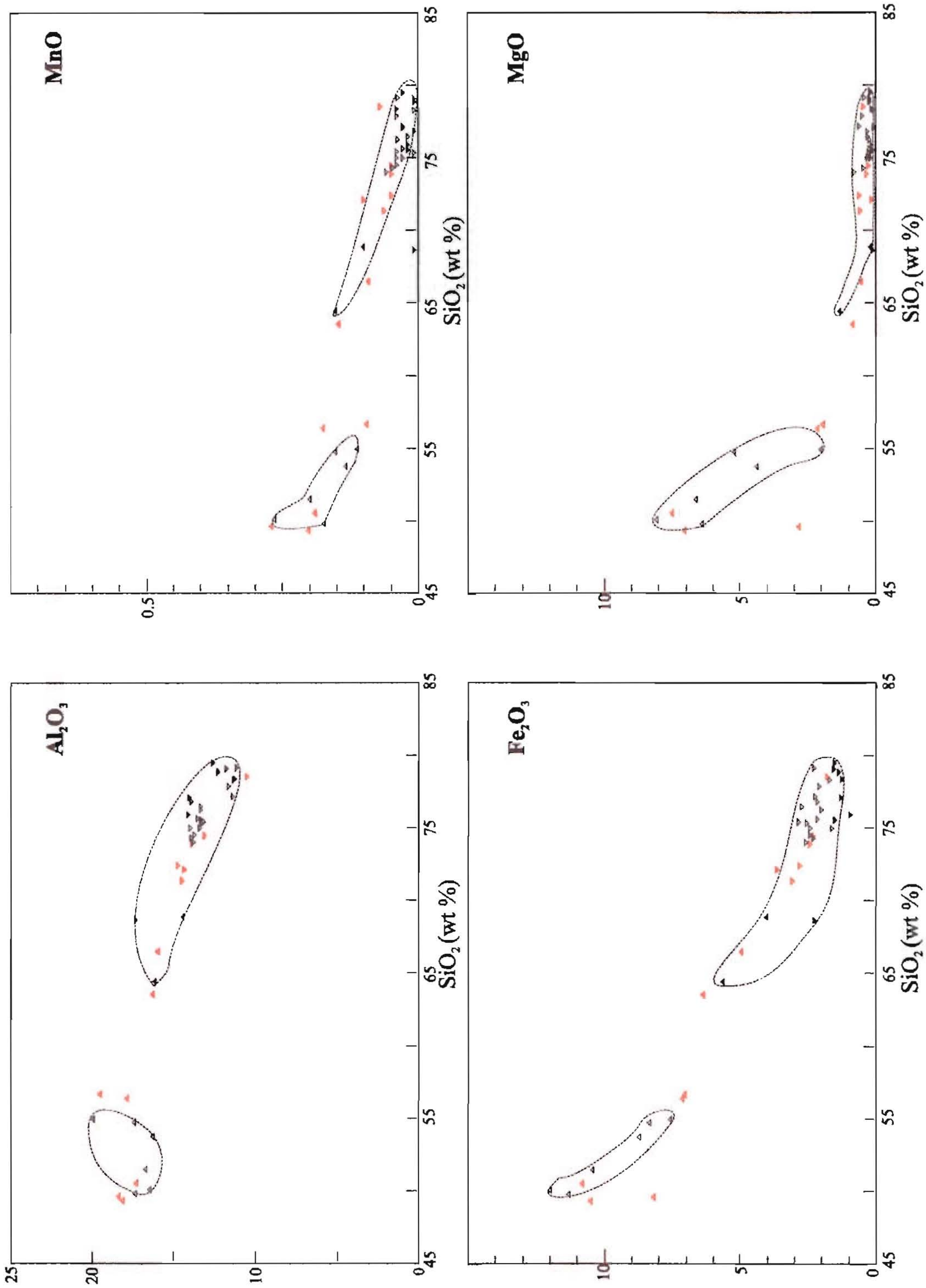


Figure 5.4: Harker variation diagrams of Al_2O_3, MnO, MgO and Fe_2O_3 for andesitic to rhyolitic rocks of the Ibáñez Formation. Samples with LOI greater than 3% are plotted in orange. Plot symbols are as in previous figures and dashed lines indicate main trends. All data plotted as Wt%.

5.2.2 Trace Elements

Trace elements for the basalts, basaltic andesites and andesites from the Ibáñez Formation are plotted on a spider diagram (Fig. 5.5), normalised to the primordial mantle composition of McDonough et al. (1992). Olivine basalts from the West Ibáñez area at Maitén (Fig. 5.5A) show considerable scatter in the mobile elements due to alteration, but overall have the most primitive trace element pattern, with moderate LIL (Light Ion Lithophile) element enrichment and HFS (High Field Strength) element depletion. Depletion spikes of Nb, Sr and Ti are present, as are depletions in Rb and K in some samples. The Nb depletion is characteristic of subduction-related sources (Wilson, 1989), whereas the negative spikes in other elements are probably due to fractionation (Sr and Ti) and leaching (K and Rb) by aqueous fluids. Basaltic andesites from Cerro Pirámide and Puerto Ibáñez (Fig. 5.5B) have less scatter of the mobile elements, and show stronger LIL enrichment and similar HFS depletion, and more pronounced Nb and Ti depletion spikes. The most evolved basic rocks sampled in the Ibáñez Formation are the basaltic andesites from the frontier region at Estero Zanjón Feo and Estancia Moroma, which show slightly greater LIL enrichment than those sampled at Puerto Ibáñez/Cerro Pirámide, similar levels of HFS depletion and a pronounced depletion spike of Nb (Fig. 5.6A). However, all the basaltic and andesitic rocks are similar in trace element trends (Fig. 5.6B). Rb/Sr ratios range from 0.002 to 1.67, and K/Rb ratios from 69–1660, although these elements are mobile and may have been affected by alteration. These lavas plot in the calc-alkali basalt fields on Ti-Zr-Y and Ti-Zr-Sr discrimination diagrams of Pearce and Cann (1973) (Fig. 5.6C and D).

Dacites, rhyolites and silicic tuffs from the Ibáñez Formation have patterns of LIL enrichment and HFS depletion which are broadly similar to the andesitic rocks, but significantly more evolved (Fig. 5.7A through C). Dacites sampled from the Puerto Rey dome and lava complex show LIL elements are enriched and HFS elements depleted, and pronounced depletion spikes of Nb, Sr and Ti. Rhyolites and tuffs from throughout the Ibáñez Quadrangle show this pattern as well, although a sample from Cerro Cabeza

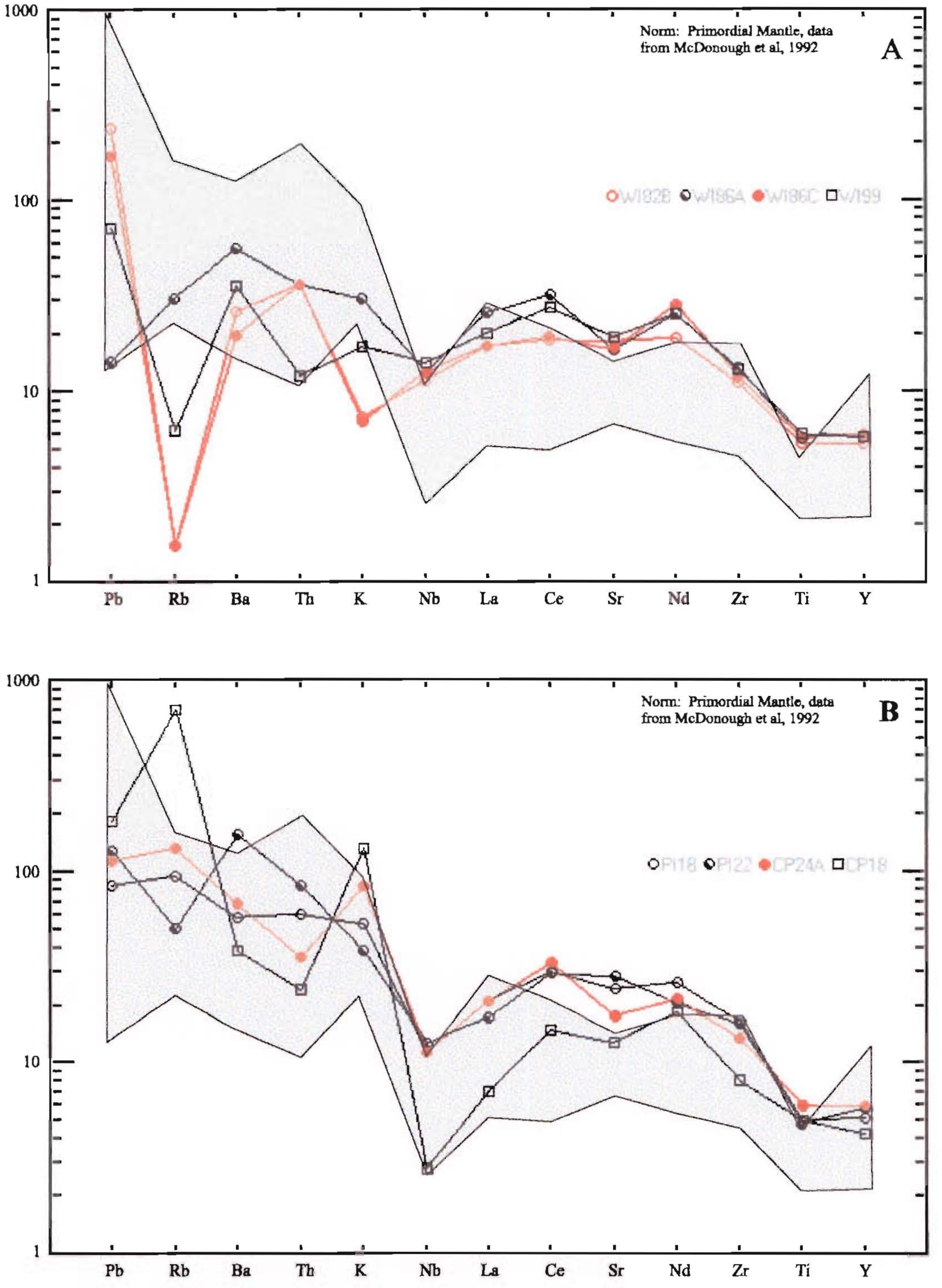


Figure 5.5: A) Trace element spider plot for olivine basalt lavas from near El Maitén, showing mild enrichment of LIL elements and depletion of HFS elements, with depletion spikes of Nb, Sr and Ti, and also strong depletion of Rb and K in some samples. Samples with LOI greater than 3% are shown in orange.
B) Trace element spider plot for basaltic andesites from Puerto Ibáñez and Cerro Pirámide, showing slightly greater LIL enrichment than those lavas at El Maitén, similar Nb, Sr and Ti depletion, and less scatter of the mobile elements. Samples with LOI greater than 3% are shown in orange.
Shaded fields show trace element ranges for andesitic rocks from Taupo Volcanic Zone, New Zealand, for comparison. Data from Burt (1999).

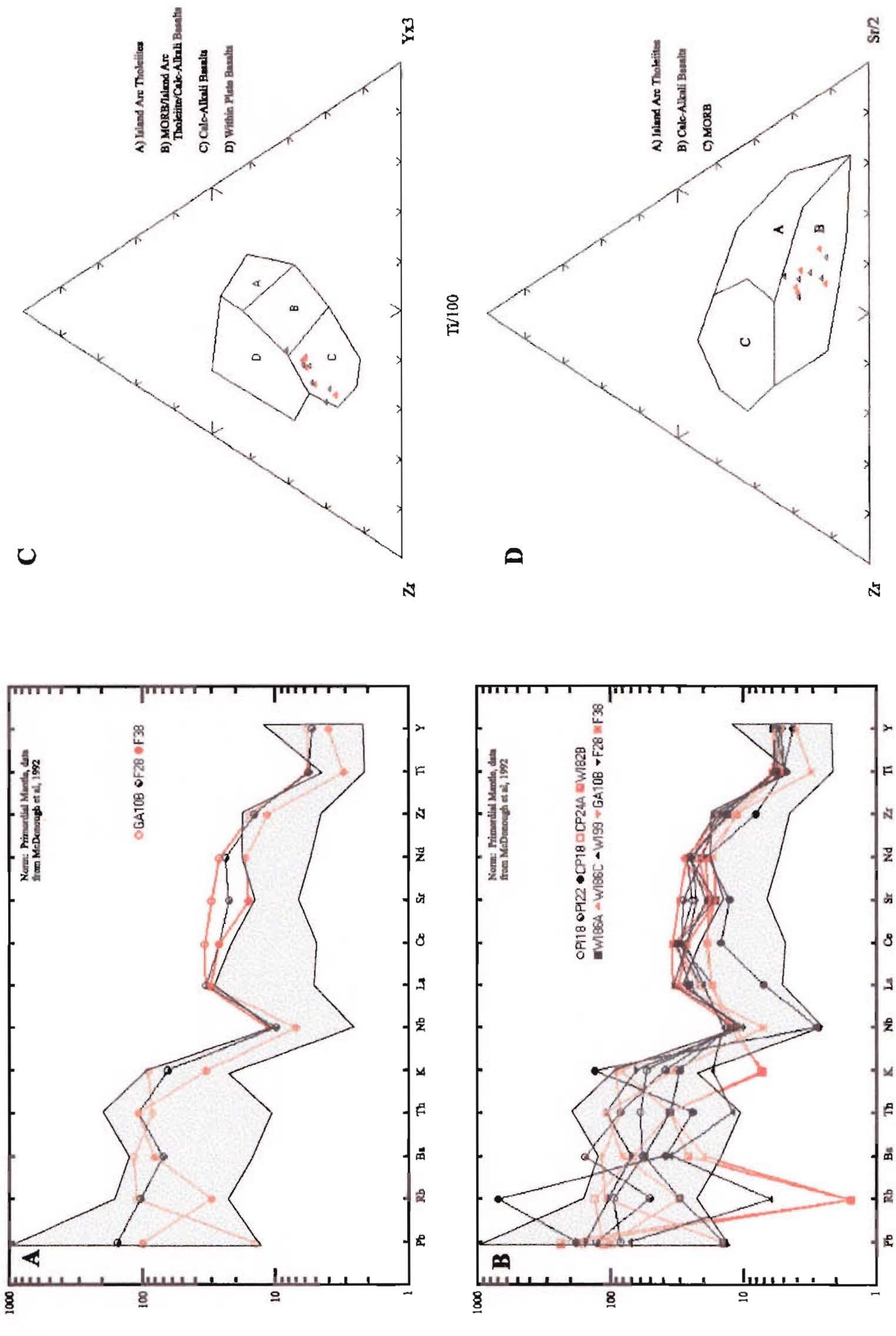


Figure 5.6: A) Trace element spider plot for basaltic andesitic lavas from Arroyo Zanjón Feo and Estancia Moroma, showing slightly greater LIL enrichment than those samples in Figs. 5.5A and B, and similar Nb and Ti depletion. Samples with LOI greater than 3% are shown in orange.
B) Trace element spider plot for all basaltic to andesitic rocks from the Ibáñez Formation showing general similarity of all samples in the HFS elements, and also the scattered nature of the mobile elements from Pb to K, most likely due to weathering and alteration. Samples with LOI greater than 3% are shown in orange.
C) Ibáñez Formation basaltic to andesitic lavas plotted on the Ti-Zr-Y discrimination diagram of Pearce and Cann, 1973. Symbols as for 5.1. Samples with LOI greater than 3% are shown in orange.
D) Ibáñez Formation basaltic to andesitic lavas plotted on the Ti-Zr-Sr discrimination diagram of Pearce and Cann, 1973. Symbols as for 5.1. Samples with LOI greater than 3% are shown in orange.

Blanca lacks the Sr depletion spike. Dacitic and rhyolitic rocks have Rb/Sr ratios of 0.14–6.7 and K/Rb ratios of 186–330, whereas the rhyolitic ignimbrites have Rb/Sr ratios of 0.19–10.4 and K/Rb ratios from 99–254, with the greater range of the Rb-Sr ratio perhaps indicating the contamination effect of lithic fragments included in the ignimbrites. The silicic rocks of the Ibáñez Formation mainly plot within the Volcanic Arc Granite field, with a few samples plotting within the Syn-Collisional Granite field, reflecting a slight enrichment in Rb, probably due to alteration, on the Rb/(Y+Nb) tectonic discrimination diagram of Pearce et al. (1984) (Fig.5.8). Their plate margin affinity, with distinctive low Nb content, is well illustrated by comparison with data from Pankhurst et al. (1998) on a Nb-Zr plot (Fig 5.9) for all the Jurassic silicic rocks of Patagonia.

5.3 Divisadero Formation

Twenty one tuffs and ignimbrites from the Divisadero Formation were sampled, five from the Ibáñez Quadrangle at Cerro Manchón, Estancia Moroma, and Arroyo Zanjón Feo, together with sixteen samples of five ignimbrites from the Divisadero Formation type section at Cerro Divisadero and from nearby exposures at Lago Frio and Lago Castor (see location map, Fig. 5.10). Well-exposed ignimbrites were sampled at base, middle and top so as to cover any internal trends. These rocks plot on the TAS classification diagram of Le Maitre (1989) as rhyolites, and are both metaluminous and peraluminous (Fig. 5.11).

5.3.1 Major Elements

Although basic rocks for the Divisadero Formation are not common and were not analysed, Harker variation plots of the Divisadero Formation are presented to illustrate the similarity of the Divisadero Formation rocks to those of the Ibáñez Formation. Plots for CaO and the alkalis are presented in Fig. 5.12, and for Al_2O_3, MnO, MgO and Fe_2O_3 in Fig. 5.13. The tuffs and ignimbrites of the Divisadero Formation are rhyolitic, quartz-hypersthene normative, and range from 69.1–77.62% SiO_2. The major element trends of Divisadero Formation rocks are essentially the same as those of rhyolitic rocks of the Ibáñez

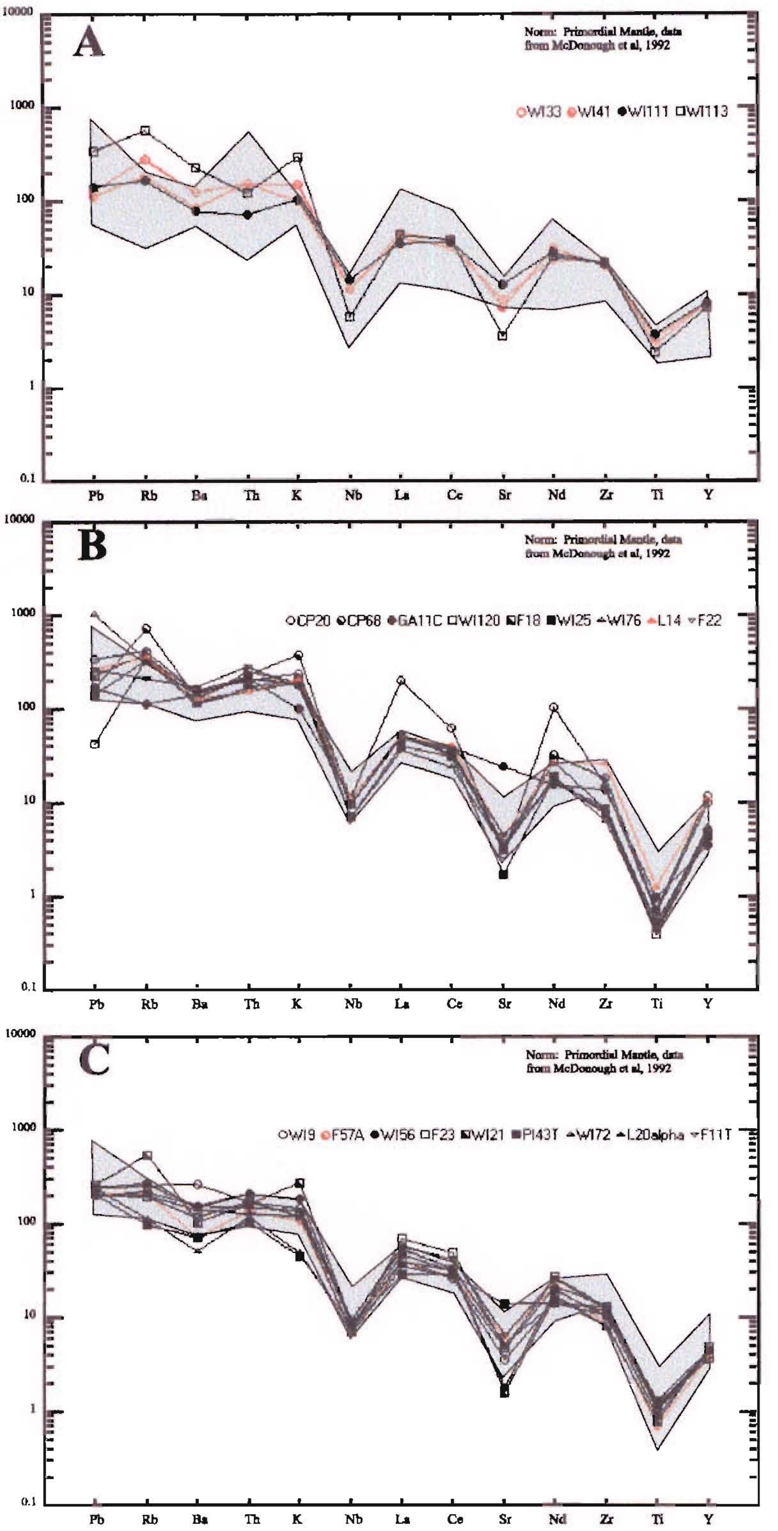


Figure 5.7: A) Trace element spider plot for dacitic lava and dome rocks from Puerto Rey, showing LIL enrichment and HFS depletion, and strong Nb, Sr and Ti depletion spikes. Samples with LOI greater than 3% are shown in orange.
B) Trace element spider plot for rhyolitic lavas of the Ibáñez Formation showing LIL enrichment and HFS depletion with marked depletion spikes of Nb, Sr and Ti. Samples with LOI greater than 3% are shown in orange.
C) Trace element spider plot for rhyolitic tuffs of the Ibáñez Formation showing LIL enrichment and HFS depletion with marked depletions spikes of Nb, Sr and Ti. Samples with LOI greater than 3% are shown in orange.
Shaded field indicates trace element ranges for dacitic (A) and rhyolitic (B & C) rocks from Taupo Volcanic Zone, New Zealand, for comparison. Data from Burt (1999).

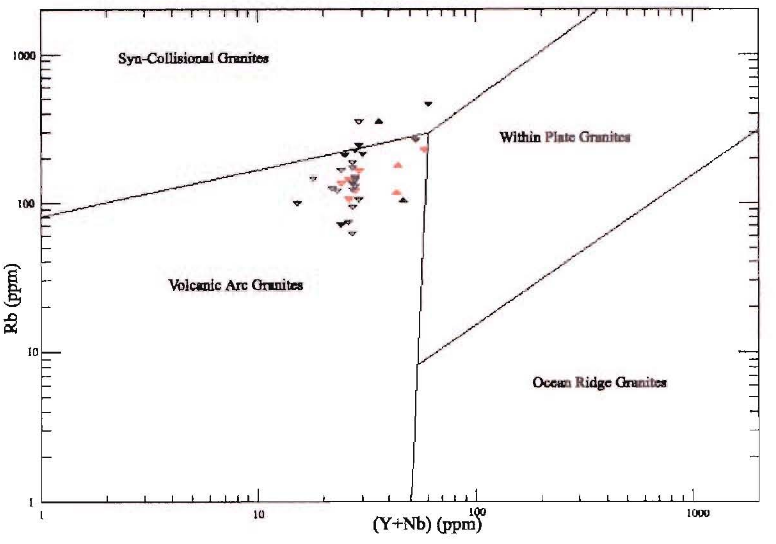


Figure 5.8: Silicic rocks of the Ibáñez Formation plotted on the Rb/(Y+Nb) granite discrimination diagram of Pearce et al. (1984). Samples with LOI greater than 3% are shown in orange.

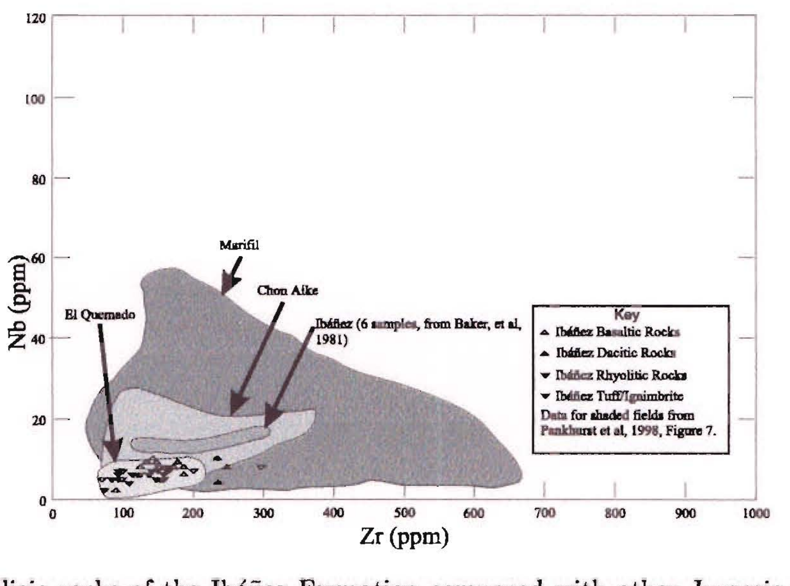


Figure 5.9: Silicic rocks of the Ibáñez Formation compared with other Jurassic silicic volcanic rocks from Patagonia, on an Nb-Zr plot after Pankhurst et al. (1998).

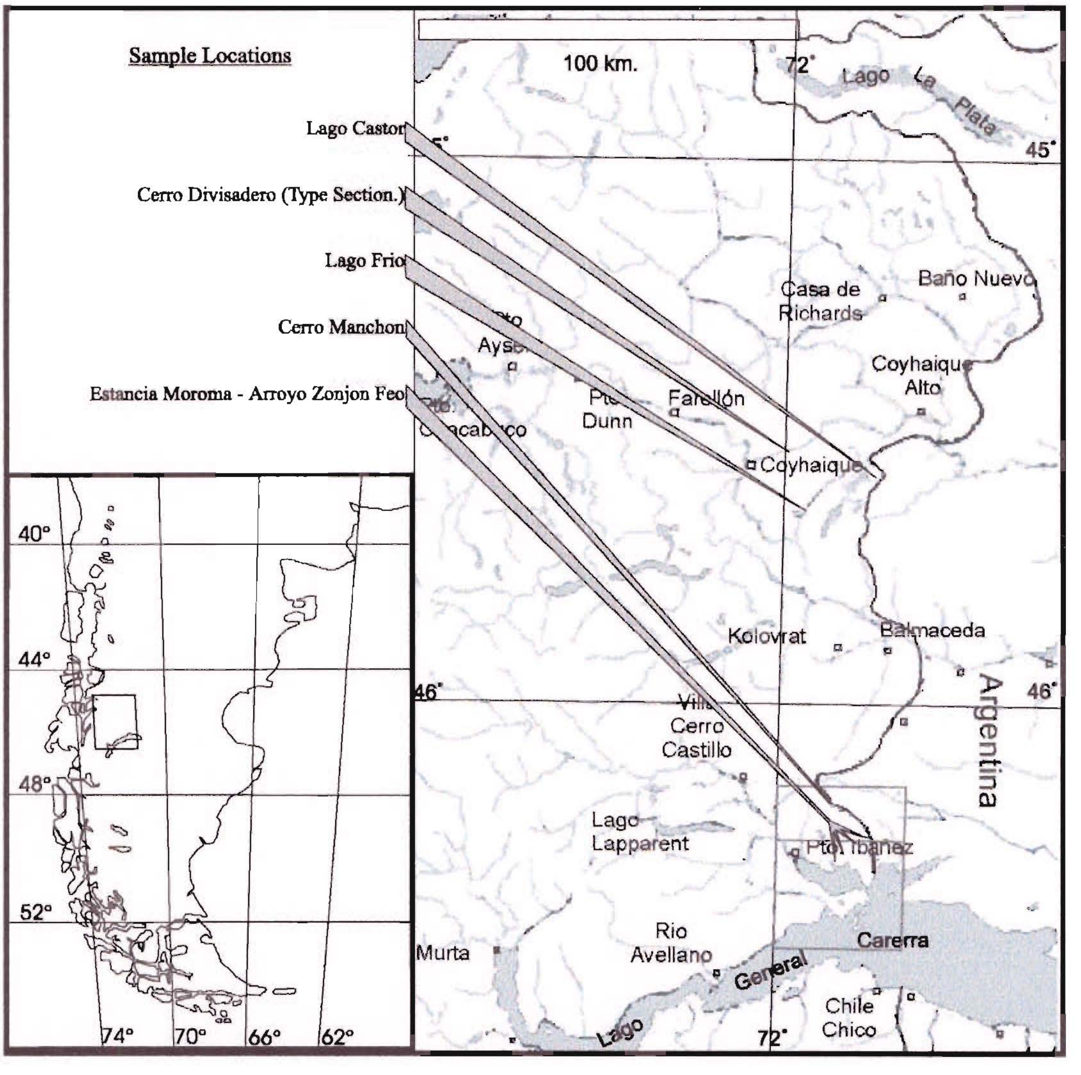


Figure 5.10: Sample locations for geochemistry within the Divisadero Formation.

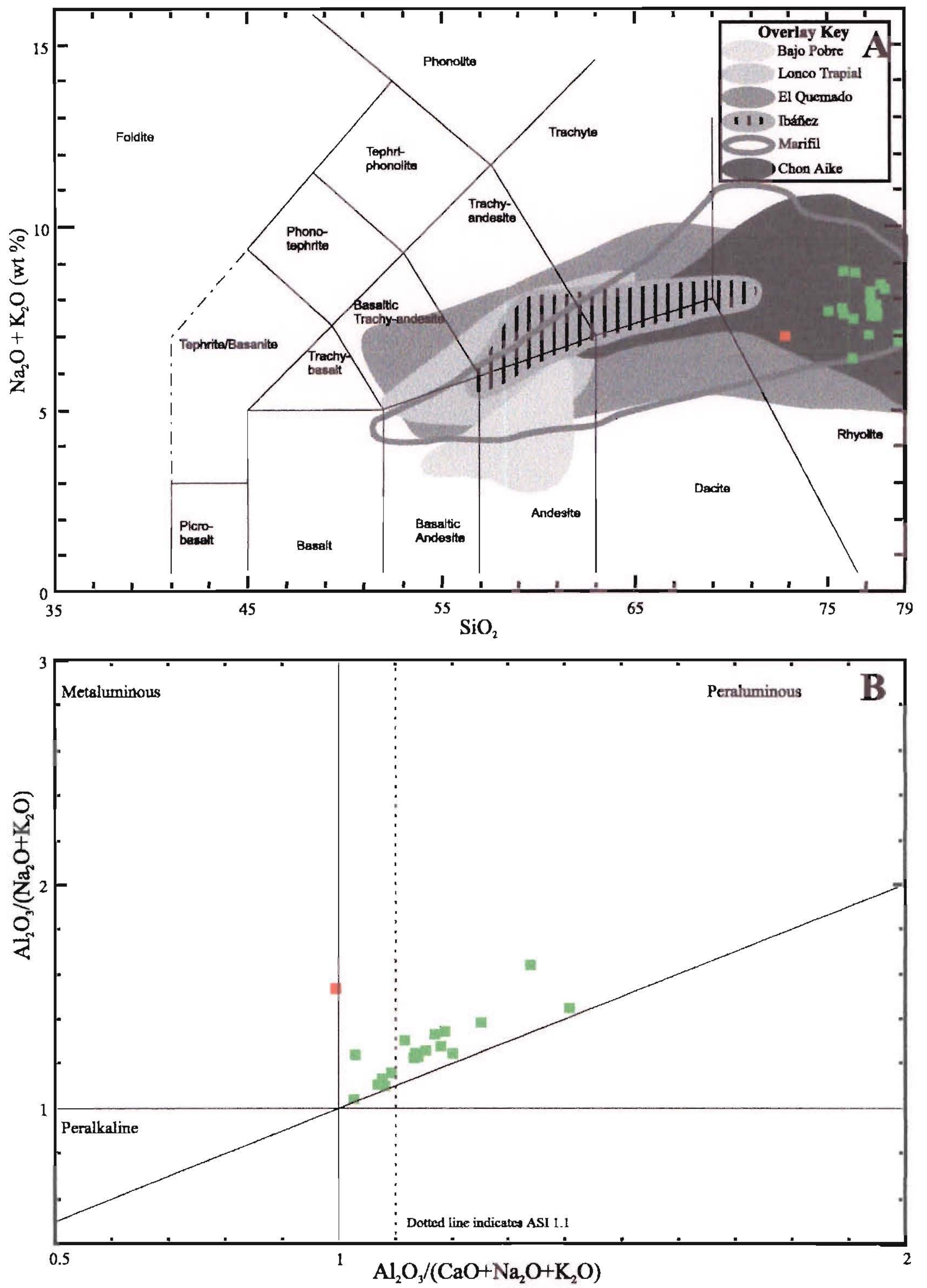


Figure 5.11: A) TAS plot for volcanic rocks of the Divisadero Formation, after Le Maitre (1989). The tuffs and ignimbrites of the Divisadero Formation are rhyolitic, and plot with a similar distribution to those of older silicic rocks in Patagonia. Data for overlay fields is from Pankhurst et al. (1998). Samples with LOI greater than 3% are shown in orange.
B) ASI plot for tuffs and ignimbrites of the Divisadero Formation, after Maniar and Piccoli (1989), ranging from slighly metaluminous to peraluminous. Samples with LOI greater than 3% are shown in orange.

Formation, and the samples plot as a tight cluster within the fields defined above for rocks from the Ibáñez Formation. Basic rock examples were not analysed due to indeterminate field evidence as to their provenance as either a sill intruding the Divisadero Formation or a lava within the Divisadero Formation, so no distinct basic to acidic compositional trends can be identified. CaO is low, Na_2O is medium to high and most samples plot as High K rather than Medium K. The Divisadero Formation samples show only occasional scatter due to alteration, and the bulk of Divisadero tuffs have similar CaO, Na_2O and TiO_2 contents and slightly higher K_2O contents than those of the Ibáñez Formation, and also a slightly lower Fe_2O_3 content.

5.3.2 Trace Elements

Ignimbrites of the Divisadero Formation show LIL enrichment and HFS depletion, and strong depletion spikes at Nb, Sr and Ti (Fig.5.14A). The Divisadero Formation rhyolitic ignimbrites plot within the trace element ranges of the older Ibáñez Formation with the exception of some samples with slightly higher Nd, and one sample with greater Nb depletion, but otherwise are similar to, if not indistinguishable from, spider plots of silicic rocks of the Ibáñez Formation, although with less scatter of data points, related to the less altered nature of the samples. (Silicic pyroclastic rocks of the Divisadero Formation often show welded glassy eutaxitic groundmass textures, rather than the partially recrystallised and altered felsitic textures shown in Ibáñez Formation examples.) Rb/Sr ratios range from 0.5–7.5, while K/Rb ranges from 199–383. As with the Ibáñez Formation, the Divisadero Formation tuffs and ignimbrites plot as Volcanic Arc Granites on the Rb/(Y+Nb) tectonic discrimination diagram of Pearce et al. (1984). (Fig.5.14B).

5.4 Cerro Pico Rojo Rhyolite Dome

This dome complex is erupted through and onto the Divisadero Formation, and is overlain by basaltic lava flows. Eight samples were analysed, from seven flowbanded lavas and one pumice flow tuff. These plot on a TAS diagram as high silica rhyolites, and are peralkaline

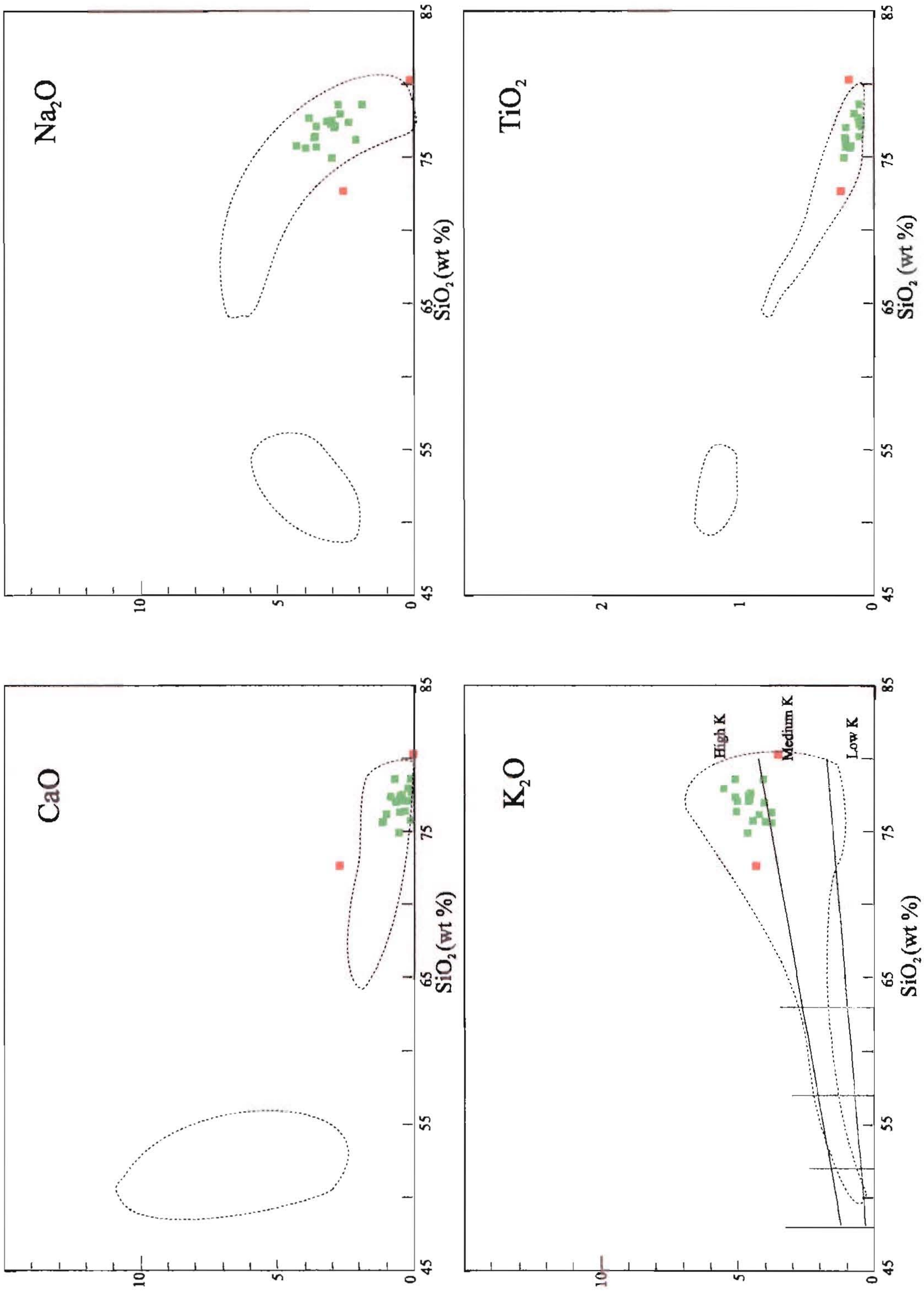


Figure 5.12: Harker variation diagrams of Na_2O, K_2O, CaO and TiO_2 for rhyolitic tuffs of the Divisadero Formation, compared to the main trends shown in Ibáñez Formation rocks (dotted fields). Fields on K_2O plot are from Le Maitre (1989). All data in Wt %. Samples with LOI greater than 3% are shown in orange.

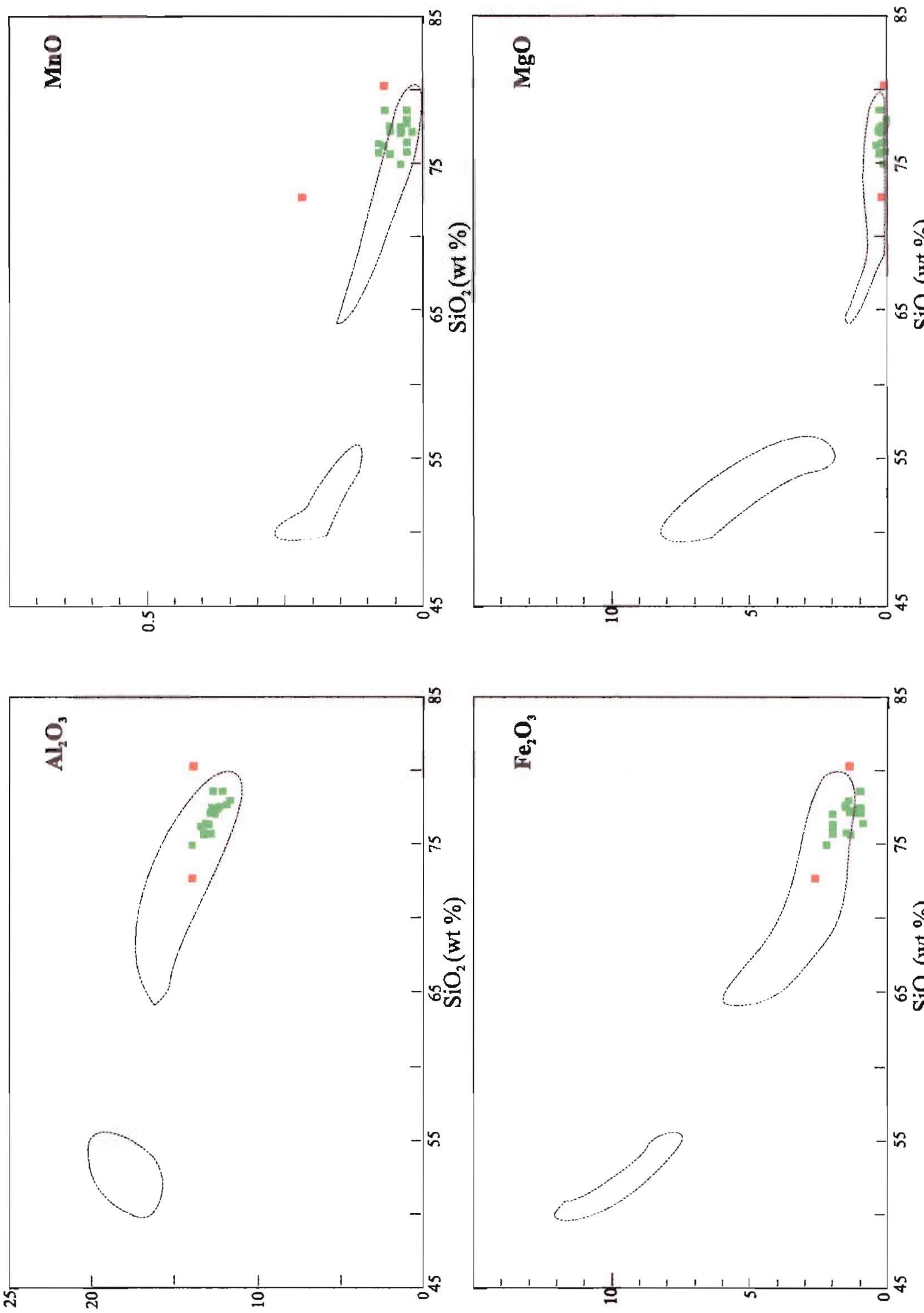


Figure 5.13: Harker variation plots of Al_2O_3, MnO, MgO and Fe_2O_3 for rhyolitic tuffs from the Divisadero Formation, compared to the main trends shown in Ibáñez Formation rocks (dotted fields). All data in Wt %. Samples with LOI greater than 3% are shown in orange.

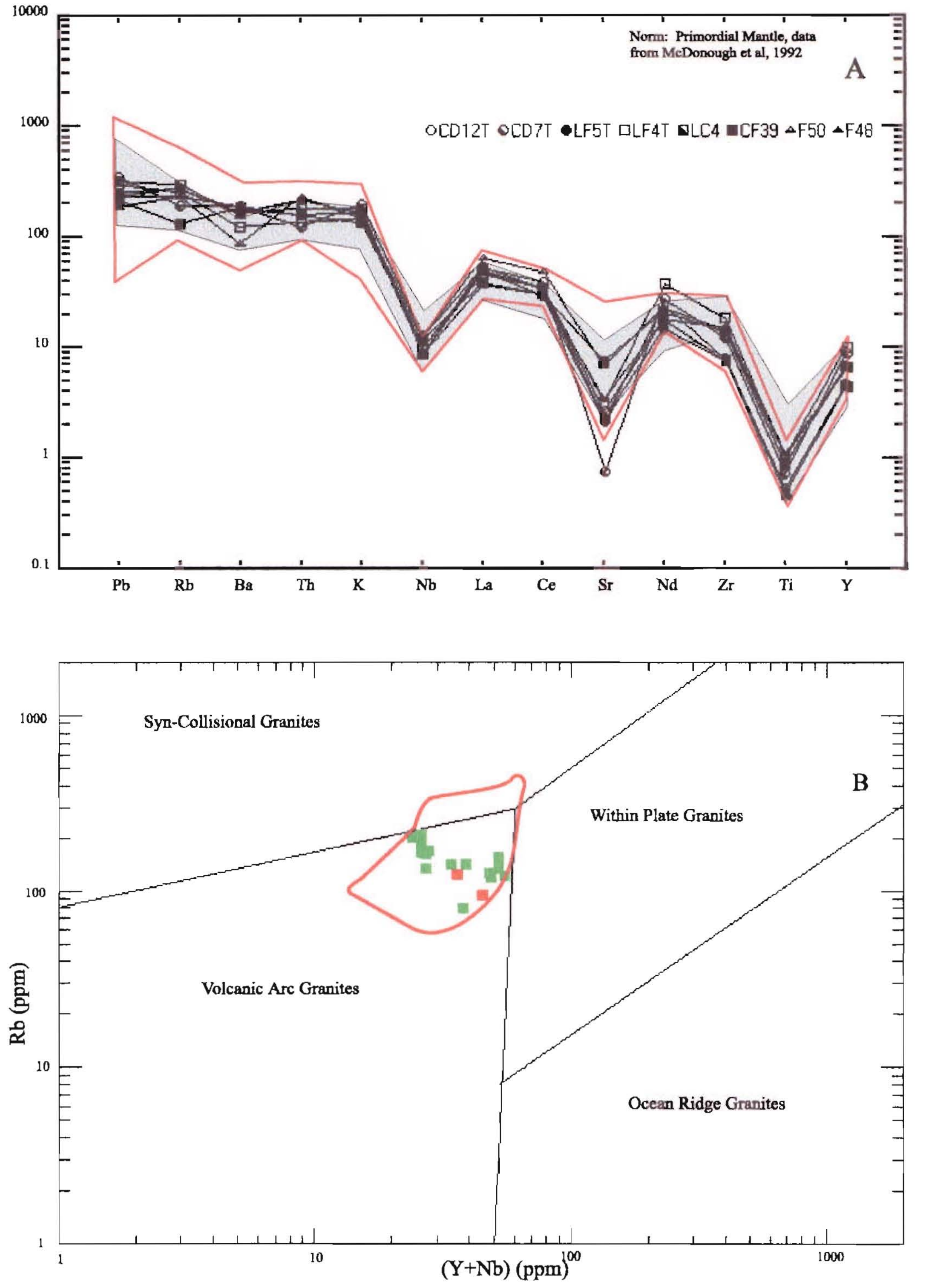


Figure 5.14: A) Trace element spider plot for rhyolitic tuffs of the Divisadero Formation. Note similarity of pattern to rhyolitic rocks of the Ibáñez Formation (red-outlined field).
B) Rb vs (Y+Nb) tectonic discrimination plot for rhyolitic tuffs of the Divisadero Formation, after Pearce et al. (1984). Red field indicates range for rhyolitic rocks of the Ibáñez Formation. Samples with LOI greater than 3% are shown in orange.
Shaded fields indicate trace element ranges for rhyolitic rocks from Taupo Volcanic Zone, New Zealand, for comparison. Data from Burt (1999).

to weakly metaluminous, and peraluminous in an altered sample, and plot as comendite on the Al_2O_3-FeO plot of Le Maitre (1989). (Fig. 5.15).

5.4.1 Major Elements

These rocks are medium to high K comenditic high silica rhyolites, with 73.5–76.5% SiO_2.

5.4.2 Trace Elements

These rocks show a markedly different trace element pattern from the calc-alkaline rhyolitic rocks of both the Ibáñez and Divisadero Formations. They have slight LIL enrichment and HFS depletion patterns, they are entirely without depletion of Nb, and have very strong depletion of Ba, Sr and Ti (Fig. 5.16A) and enrichment in Zr, typical of peralkaline felsic rocks. The pattern shown is very similar to that of a phonolitic sill cutting the Ibáñez Formation at Peninsula Levicán (see Fig. 5.27B). These rhyolites have high Rb/Sr ratios ranging from 1.7–90, and K/Rb ratios from 130–188, and plot well within the Within Plate Granite field on the Rb-(Y+Nb) discrimination diagram of Pearce et al. (1984) (Fig. 5.16B).

5.5 Plateau Basalts

These rocks occur as plateau lavas overlying the Divisadero Formation and Cerro Pico Rojo Rhyolite. Three samples were analysed, all from lava flows. These samples plot on a TAS diagram as basalt, trachy-basalt and basaltic trachy-andesite (Fig. 5.17) and are metaluminous.

5.5.1 Major Elements

These three samples are quartz-hypersthene normative, with 47.3–52.6% SiO_2. They have moderate K_2O levels, plotting as medium and high K, and are high in TiO_2. Although the data set is small, weak trends can be determined: CaO, TiO_2, Fe_2O_3 and MgO decrease

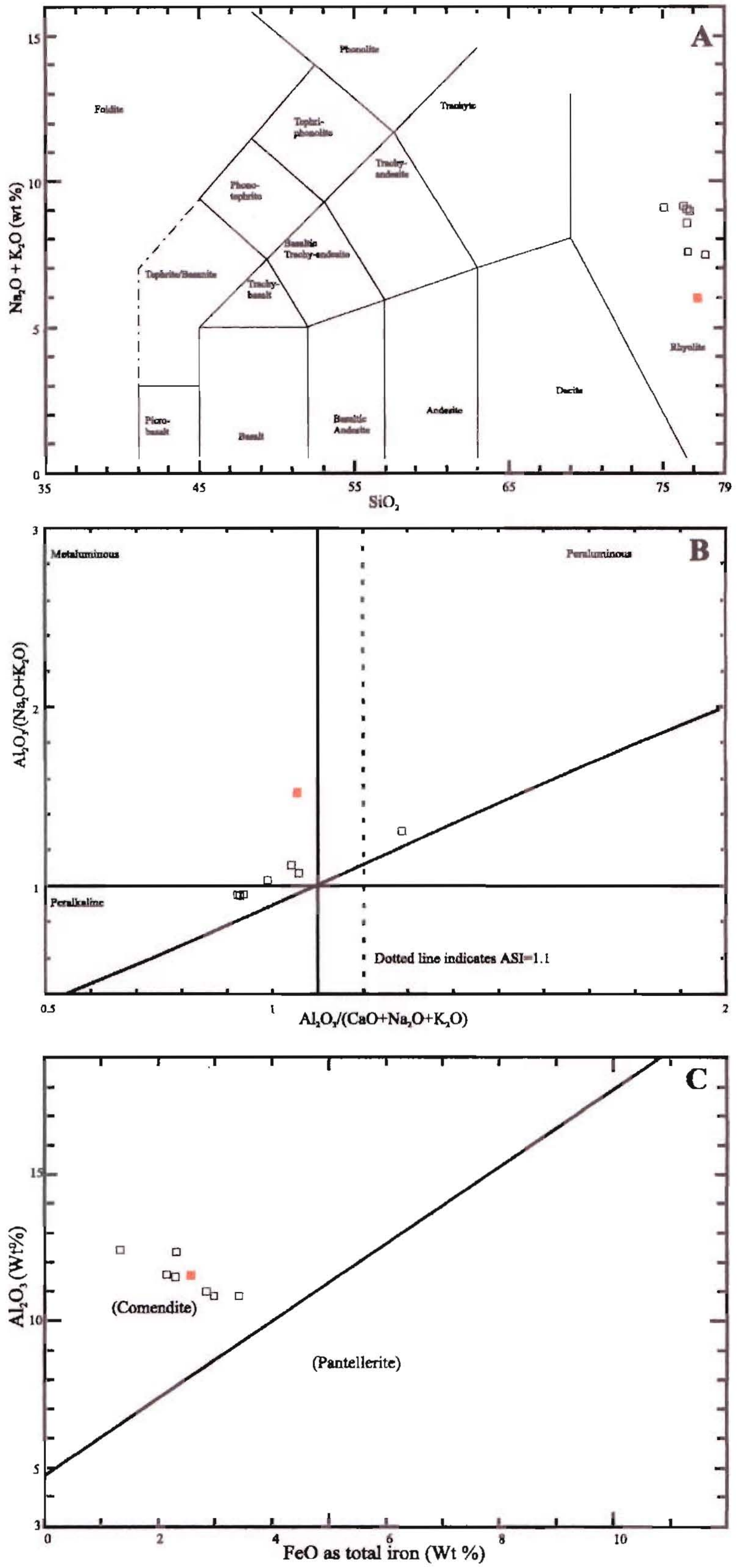


Figure 5.15: A) TAS plot for lava, dome and tuff samples from Cerro Pico Rojo and adjacent exposures, after Le Maitre (1989). Samples with LOI greater than 3% are shown in orange.
B) ASI plot for rocks from Cerro Pico Rojo and adjacent exposures, after Maniar and Piccoli (1989). Samples with LOI greater than 3% are shown in orange.
C) Alumina/Total Iron plot for rocks from Cerro Pico Rojo, after Le Maitre (1989). Samples with LOI greater than 3% are shown in orange.

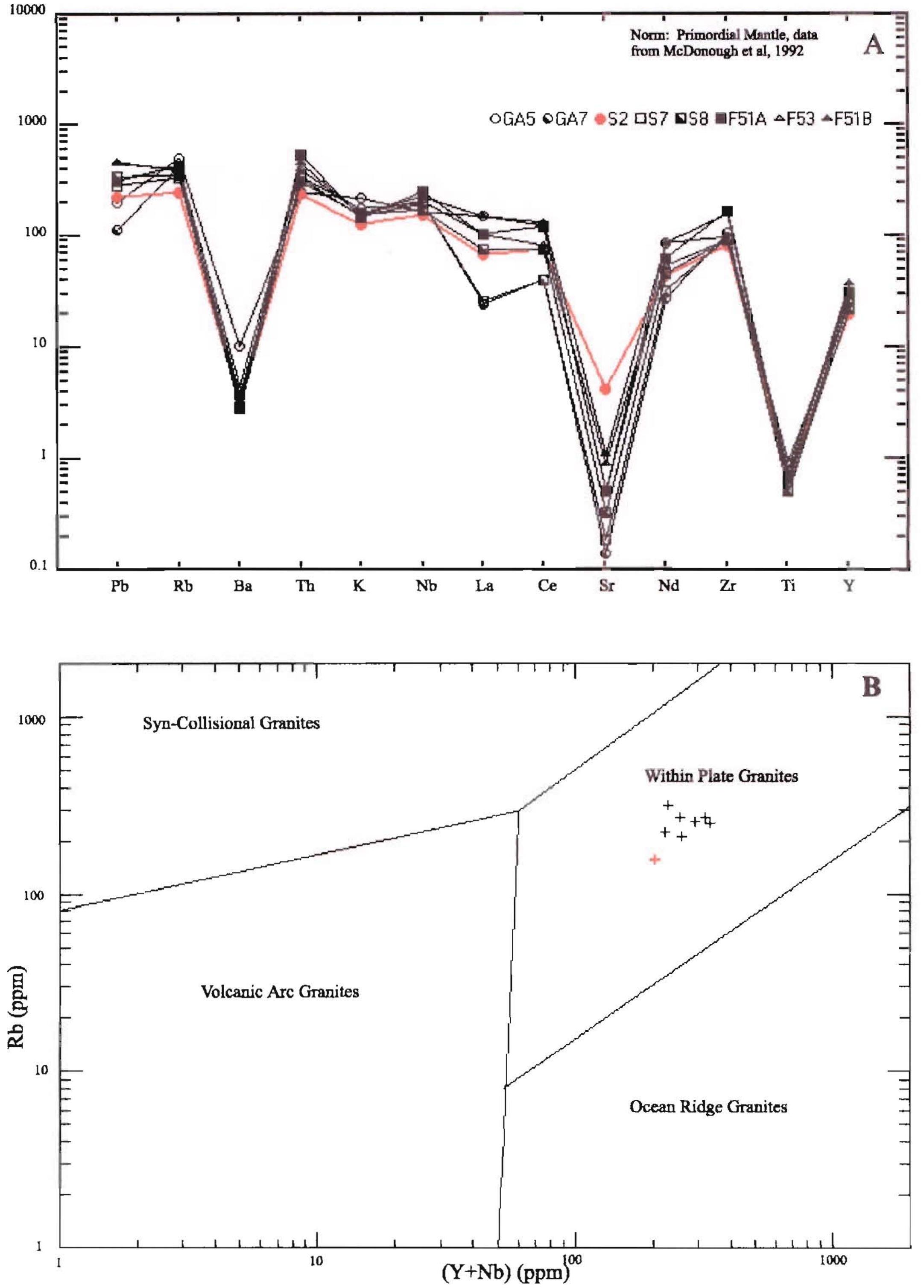


Figure 5.16: A) Trace element spider plot for dome, lava and tuff samples from Cerro Pico Rojo and adjacent exposures, showing moderate HFS depletion and LIL enrichment, and strong depletion spikes of Ba, Sr and Ti. Samples with LOI greater than 3% are shown in orange.
B) Rb vs (Y+Nb) tectonic discrimination plot for dome, lava and tuff samples from Cerro Pico Rojo, after Pearce et al. (1984). Samples with LOI greater than 3% are shown in orange.

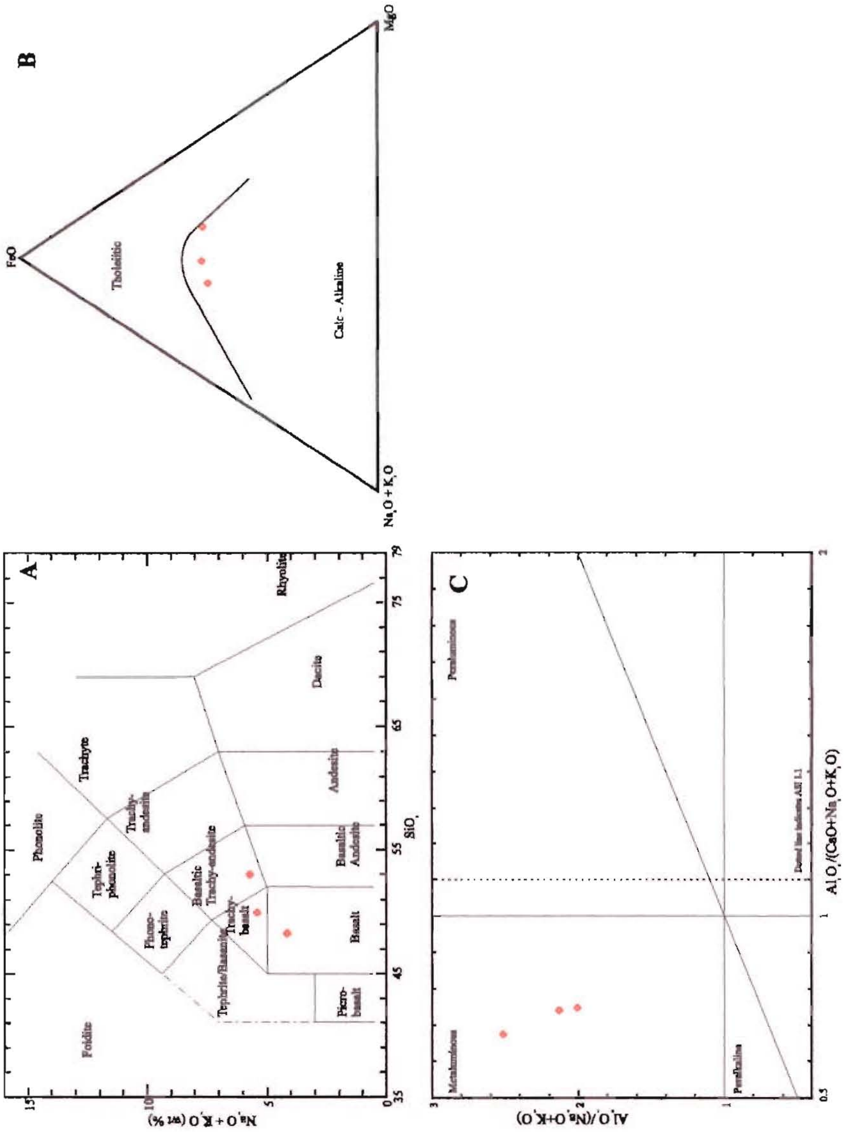


Figure 5.17: A) TAS plot for three lavas sampled from the Plateau Basalts, after Le Maitre (1989).).
B) AFM plot for three Plateau Basalt lavas, after Irvine and Barragar (1971).
C) ASI plot for three Plateau Basalt lavas, after Maniar and Piccoli (1989).

with increasing SiO_2, while K_2O, Al_2O_3 and Na_2O increase slightly, and MnO shows no distinct trend (Fig. 5.18).

5.5.2 Trace Elements

These rocks have flatter and more primitive trace element patterns than the basic rocks of the Ibáñez Formation, without the Nb depletion spike of the underlying Mesozoic volcanic rocks, and with less enrichment of LIL elements and also less depletion of HFS elements (Fig. 5.19). They have low Rb/Sr ratios from 0.03–0.06, and high K/Rb ratios of 389–592. On the tectonic discrimination diagram of Pearce and Cann (1973), these three lavas plot between the Within Plate basalt and Calc-Alkali basalt fields for the Ti-Zr-Y plot and in the Within Plate Basalt field on the Zr/Y-Zr plot of Pearce and Norry (1979).

5.6 Minor Intrusive Rocks

Forty three minor intrusive bodies were sampled, and represent a complex group of dikes, sills and stocks. These rocks are plotted according to their field occurrence, thus different symbols for each group: 'Minor Intrusive Rocks cutting the Ibáñez Formation' etc. They show three distinct trends on a TAS diagram, with a calc-alkaline series from basaltic to rhyolitic, and two alkaline series, one of basaltic trachy-andesites to trachy-andesites, the other mugearitic to phonolitic. The trachytic series and the calc-alkaline series overlap, and given the more weathered nature of the trachytic series, and their high LOI values, their identification as trachytic is spurious and they may be altered examples of the calc-alkaline series. These rocks are dominantly metaluminous, with only three peraluminous samples and one peralkaline phonolite (Fig. 5.20).

5.6.1 Major Elements

There are three distinct trends among these rocks, one calc-alkaline and two alkaline. Various lesser trends can be determined on Harker variation diagrams, often relating to groups of similar rocks by their field occurrence, although some of these trends may be

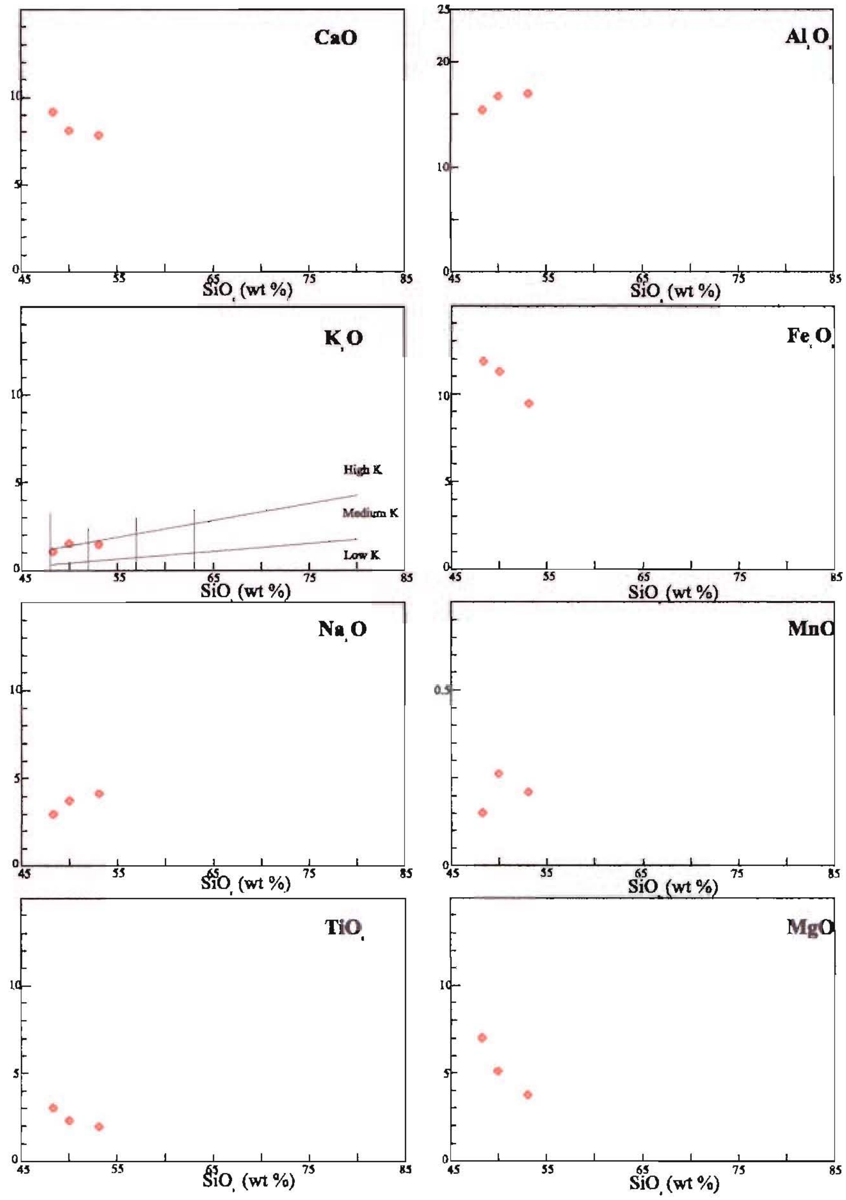


Figure 5.18: Harker variation diagrams for three Plateau Basalt lavas.

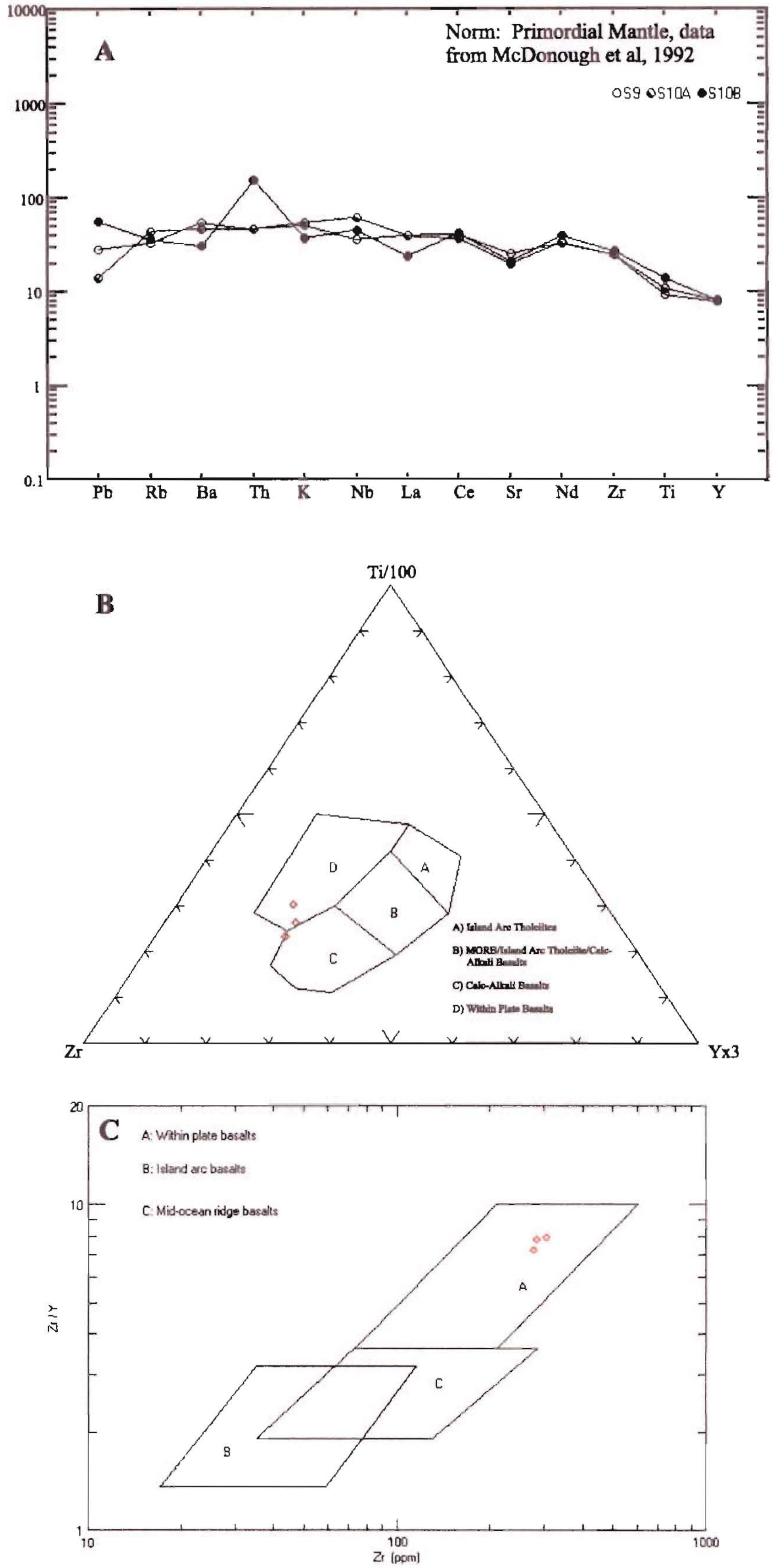


Figure 5.19: A) Trace element spider plot for three Plateau Basalt lavas, showing slight HFS depletion and Sr depletion spike, and Th enrichment in one sample.
B) Zr-Ti-Y tectonic discrimination plot for the Plateau Basalt lavas, after Pearce and Cann (1973).
C) Zr/Y-Zr tectonic discrimination plot for the Plateau Basalt lavas, after Pearce and Norry (1979).

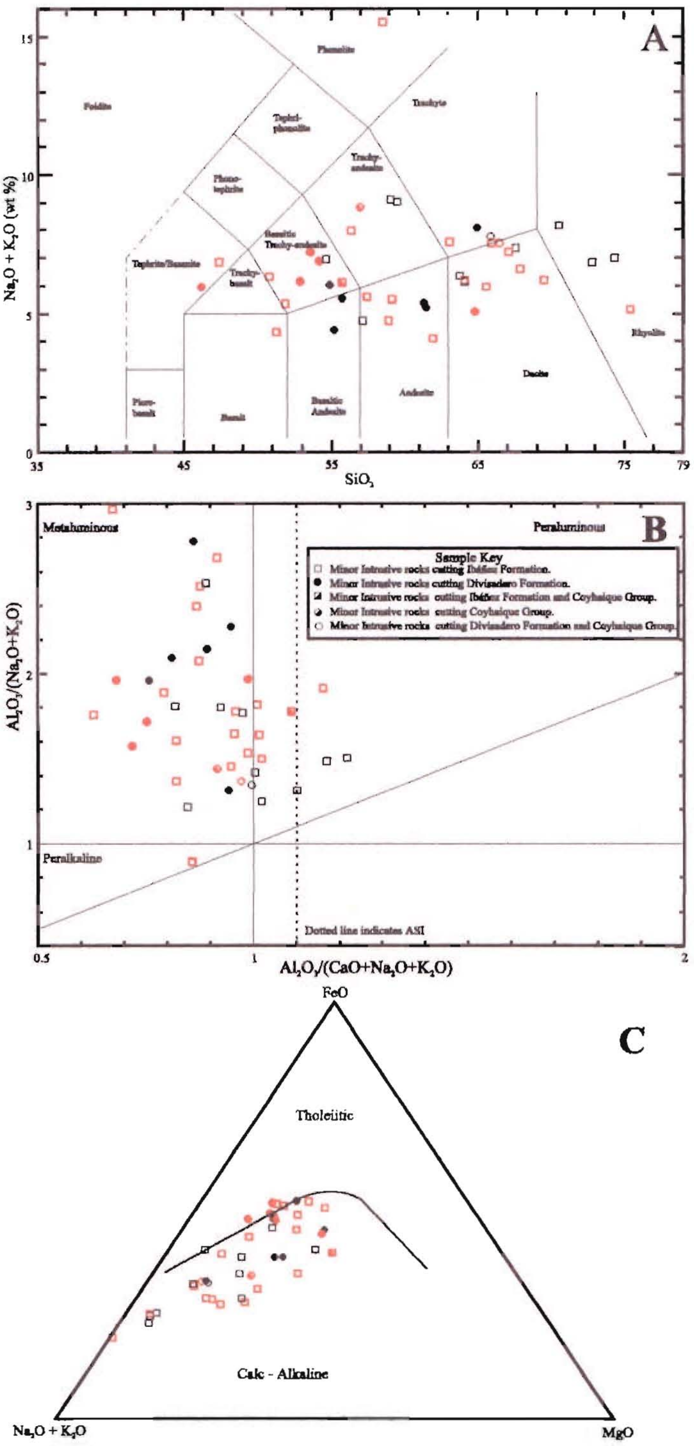


Figure 5.20: A) TAS plot for Minor Intrusive rocks from the Ibáñez Quadrangle. Three trends can be identified, one calc-alkaline basaltic to rhyolitic, one alkaline trend from trachy-basaltic to trachy-andesitic and one strongly alkaline trend (3 samples only) from mugearitic to phonolitic. TAS fields after Le Maitre (1989). Samples with LOI greater than 3% are shown in orange.
B) ASI plot for Minor Intrusive rocks from the Ibáñez Quadrangle, after Maniar and Piccoli (1989). Samples with LOI greater than 3% are shown in orange.
C) AFM plot for Minor Intrusive rocks from the Ibáñez Quadrangle, after Irvine and Barragar (1971). Samples with LOI greater than 3% are shown in orange.

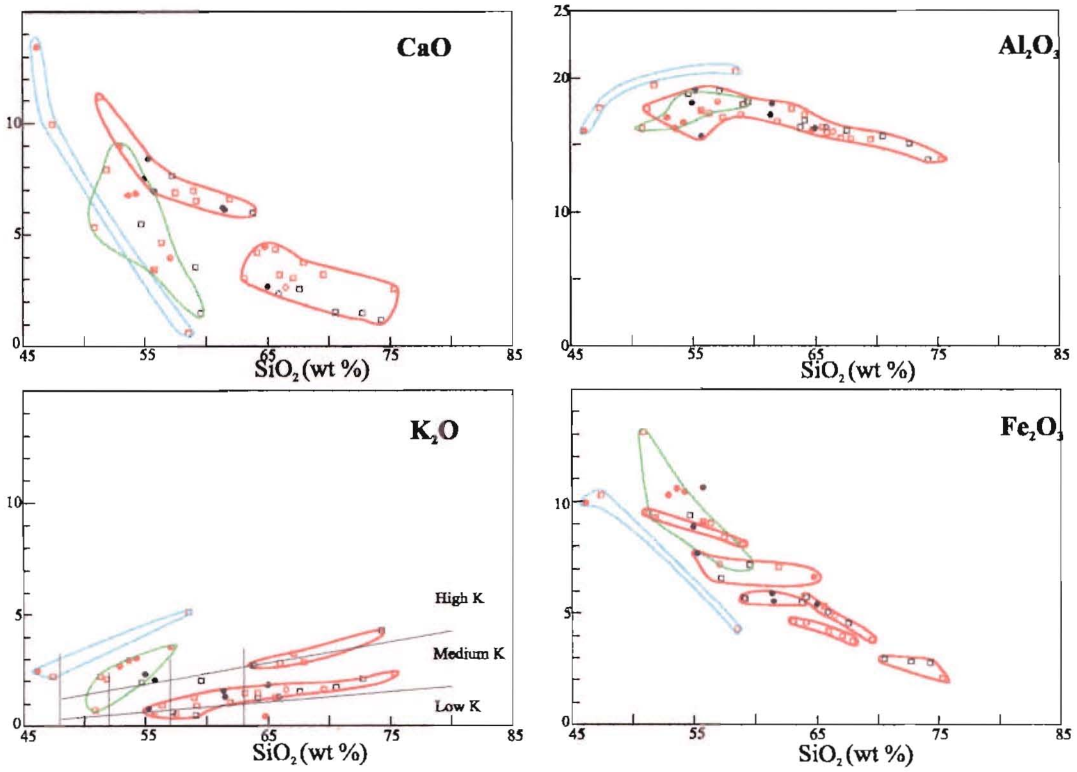


Figure 5.21: Harker variation diagrams for Minor Intrusive rocks in the Ibáñez Quadrangle. Fields on the K_2O-SiO_2 plot are after Le Maitre (1989). Possible trends are marked in red for calc-alkaline basaltic to rhyolitic rocks, green for the first alkaline trend of trachybasaltic to trachy-andesitic rocks, and blue for the second alkaline trend of two mugearites and a phonolite. Samples with LOI greater than 3% are shown in orange.

spurious due to the often high LOI values of these rocks, and there is little stratigraphic control on the minimum age of those minor intrusive rocks which cut the older formations (Fig. 5.21 and 5.22).

The calc-alkaline minor intrusive rocks are basalts, basaltic andesites, andesites, dacites, rhyodacites and rhyolites. Calc-alkaline basaltic to andesitic rocks are quartz-hypersthene normative, and range from 47.5–61.1% SiO_2. Trachy-dacitic, dacitic and rhyolitic rocks are quartz-hypersthene normative and have SiO_2 from 60.94–72.81%. CaO is low to moderate. Samples mainly plot as medium K with some high and low K outliers. The calc-alkaline rocks show distinct trends on the Harker variation diagrams (Fig. 5.21 and 5.22, red fields), with one, two or more trends identifiable depending upon the element plotted. CaO shows a distinctly bimodal plot, with basic and silicic samples plotting separately, both decreasing with SiO_2. K_2O plots two positive gradient fields which overlap

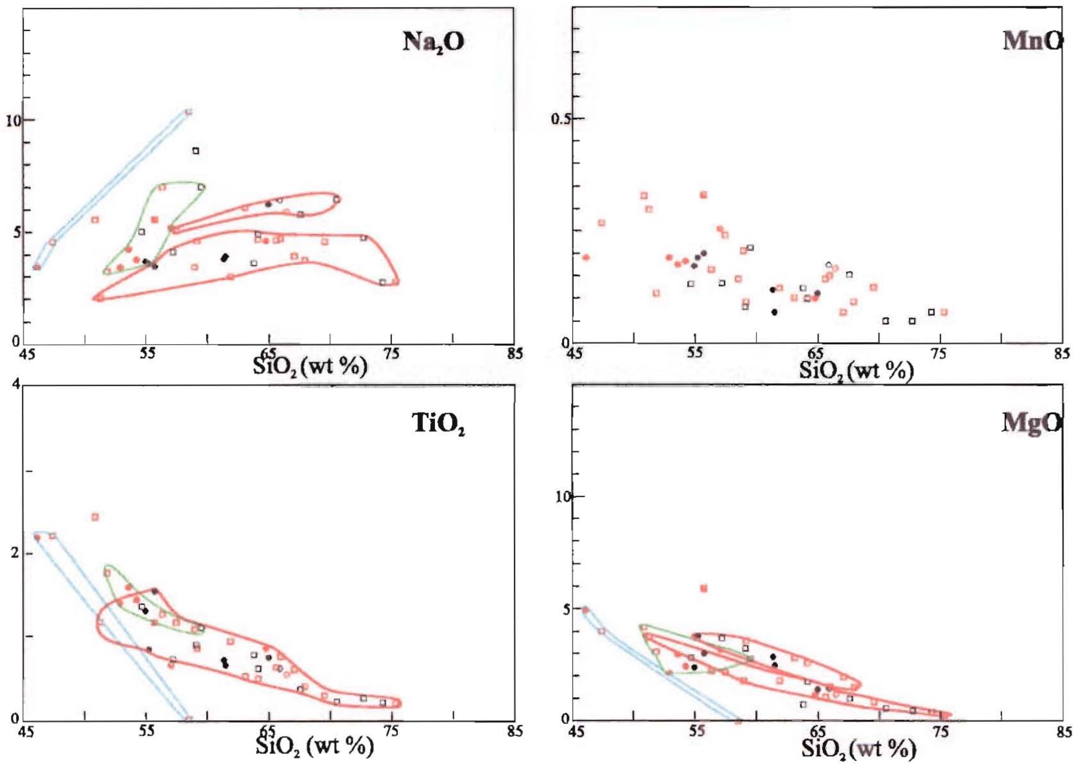


Figure 5.22: Harker variation diagrams for Minor Intrusive rocks in the Ibáñez Quadrangle. Possible trends are marked in red for calc-alkaline basaltic to rhyolitic rocks, green for the first alkaline trend of trachybasaltic to trachy-andesitic rocks, and blue for the second alkaline trend of two mugearites and a phonolite. Samples with LOI greater than 3% are shown in orange.

in silica content, with most samples plotting as low to medium K, and a second sparse series which plot as medium to high K. Two fields are also distinguishable on a plot of MgO, decreasing with SiO_2. TiO_2 plots only one field, decreasing with SiO_2 while Al_2O_3 also has one distinguishable trend, being initially high and increasing slightly before decreasing with SiO_2. Fe_2O_3 has a general trend decreasing from around 10% in basaltic rocks to 2–3% in silicic samples, but can be divided into six separate fields, some of which, particularly in the dacitic and trachy-dacitic samples, can be related to spatially related sills and stocks intruding the Divisadero and Ibáñez Formations at Estancia Moroma, and a series of dacitic dikes cutting the Ibáñez formation at Cerro Pirámide.

The first alkaline trend is basaltic trachyandesitic to trachyandesitic. Most rocks are quartz-hypersthene normative, but their classification is suspect due to their high LOI values (see Appendix B). They range from 45.6–57.6 % SiO_2 and plot as medium and high K. These rocks are lower in SiO_2 and of narrower compositional range than the calc-alkaline minor intrusive rocks, and although found throughout the field area, are mainly present as sills or dikes in the upper Ibáñez Formation and the Divisadero Formation. CaO decreases with SiO_2, plotting in a diffuse field between the trends of the basic calc-alkaline rocks and the strongly alkaline rocks. Their K_2O range plots in a diffuse field between the two other groups, from medium to high K, as does Na_2O, both plots having positive gradient. Fe_2O_3, TiO_2 and MgO plots have a narrow field that overlaps with the basic portion of the trend for the calc-alkaline rocks, although some of the alkaline rocks are higher in iron and titanium. Unlike the calc-alkaline rocks, no obvious internal trends within the mildly alkaline rocks can be determined.

The second strongly alkaline trend has only three samples, two mugearites and a phonolite. These are nepheline or olivine-nepheline normative, with SiO_2 at 43.0, 45.5 and 56.1%. These rocks are too few to interpret reliably, but they show the most basic and alkaline chemistry of all the minor intrusive rocks, with steeper gradients and earlier trends than the other groups (see blue fields, Fig. 5.21 and 5.22). Depletion trends of TiO_2, CaO, MgO and Fe_2O_3 plot to the left of the mildly alkaline and calc-alkaline rocks, and all three samples plot as high K and show steeply increasing gradients of K_2O, Na_2O and Al_2O_3 to the left of the other groups.

5.6.2 Trace Elements

Both the calc-alkaline basaltic to andesitic rocks and the trachy-basaltic to trachy-andesitic minor intrusive rocks cutting the Ibáñez and Divisadero Formations share broadly similar trace element trends, with all plots showing LIL enrichment, HFS depletion and some degree of a depletion spike at Nb, Sr and Ti (Fig. 5.23). LIL trends in the minor intrusive rocks are variable, with basaltic trachy-andesites cutting the Ibáñez Formation and Coyhaique Group (Fig. 5.23B) showing well defined Rb depletion and no Ti depletion in two samples, while basaltic trachy andesites cutting the Divisadero Formation (Fig. 5.23D) are all similar with a slight Ba depletion. LIL elements in the calc-alkaline basaltic andesites and andesites cutting the Ibáñez Formation are scattered, showing no clear trends, as are those of the basaltic andesites and andesites cutting the Divisadero Formation. HFS elements for these rocks plot in a narrower trend, with depletion spikes of Nb and Ti present to some degree in all samples, whereas only basaltic and andesitic rocks cutting the Ibáñez Formation (Fig. 5.23A) and basaltic trachy-andesites cutting the Divisadero Formation (Fig. 5.23D) show slight but clear Sr depletion spikes. The calc-alkaline basaltic andesites and andesites which cut the Divisadero Formation at Cerro Manchón and north of Cerro Pico Rojo show the least coherent trends, with scattered LIL elements, poorly defined Nb depletion and a slight Sr enrichment in some samples (Fig. 5.23C). When plotted on the tectonic discrimination diagrams of Pearce and Cann (1973), on the Ti-Zr-Y plot these rocks fall mainly in the Calc-Alkali Basalt field, with some outliers towards the MORB and Within Plate fields, while on the Ti-Zr-Sr they plot well to the middle of the Calc-Alkali Basalt field, again with an outlier towards the MORB field (Fig.5.24). The basaltic to andesitic minor intrusives have Rb/Sr ratios from 0.016–0.18 and K/Rb ratios from 206–409. Basaltic trachy andesite to trachy-andesites have Rb/Sr ratios from 0.02–0.36 and K/Rb from 182–652.

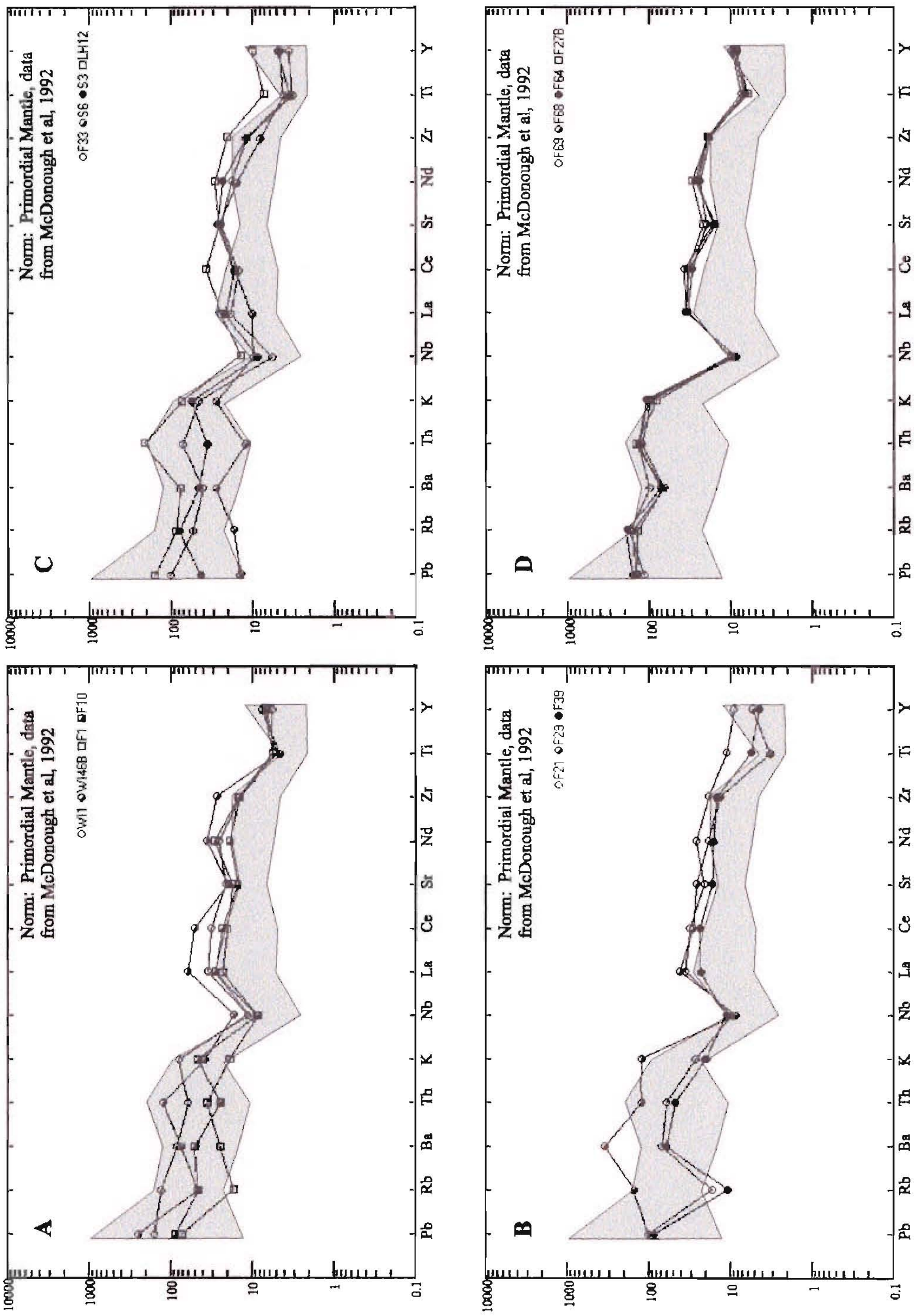


Figure 5.23: A) Trace element spider plot for calc-alkaline basaltic and andesitic dikes and sills cutting the Ibáñez Formation. All samples in A) have LOI above 3%.
B) Trace element spider plot for alkaline basaltic trachy-andesitic and trachy-andesitic dikes and a vent plug (F29) cutting either the Ibáñez Formation (F21) or the Ibáñez Formation and Coyhaique Group. All samples in B) have LOI above 3%.
C) Trace element spider plot for calc-alkaline basaltic-andesitic and andesitic sills, dikes and stocks cutting the Divisadero Formation.
D) Trace element spider plot for alkaline basaltic trachy-andesitic sills and dikes cutting the Divisadero Formation. Sample F64 has LOI above 3%.
Shaded fields show trace element ranges for andesitic rocks from Taupo Volcanic Zone, New Zealand, for comparison. Data from Burt (1999), pers. comm.

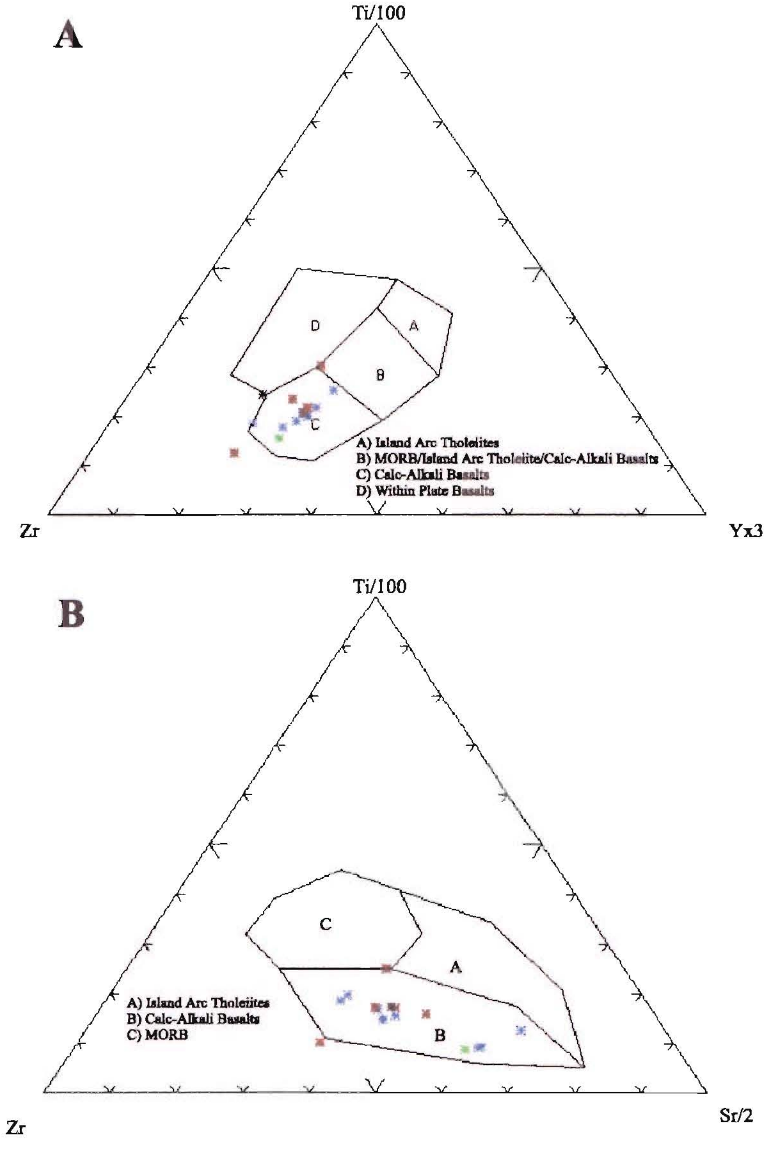


Figure 5.24: A) Zr-Ti-Y tectonic discrimination plot for some calc-alkaline basaltic and basaltic andesitic minor intrusive rocks, after Pearce and Cann (1973).
B) Zr-Ti-Sr tectonic discrimination plot for some calc-alkaline basaltic and basaltic andesitic minor intrusive rocks, after Pearce and Cann (1973).

Calc-alkaline dacitic rocks also show a similar pattern of LIL enrichment and HFS depletion, with a steeper slope and greater depletion of Nb and Ti, and the slight Sr depletion spike present in some of the basaltic-andesitic and trachy-andesitic rocks is more apparent (Fig. 5.25). Dacitic dikes cutting the Ibáñez Formation at Cerro Pirámide also show marked depletion in Ba, although the sample of a dacite dike cutting the Ibáñez Formation at Puerto Rey does not (Fig. 5.25A). The pattern present in the dacites is also present in the rhyolitic minor intrusive rocks cutting the Ibáñez Formation, with more pronounced Nb, Sr and Ti depletion spikes (Fig. 5.25B) and some Ba depletion. The rhyolitic dikes from Cerro Cabeza Blanca show a more enriched pattern, particularly in LIL elements, than do the rhyolitic sills from Maitén. The dacitic to rhyodacitic complex of stocks and dikes that cuts the Ibáñez Formation, Coyhaique Group and Divisadero Formation between La Pedregasa and Estancia Moroma also shows a similar pattern of closely overlapping plots, but with less Ba depletion than in the dacitic rocks which cut the Ibáñez Formation at Cerro Pirámide (Fig. 5.25C). Dacitic and rhyodacitic minor intrusive rocks have Rb/Sr ratios from 0.02–0.44 and K/Rb ratios from 229–557. The rhyolitic minor intrusive rocks have Rb/Sr ratios from 0.32–1.17, and K/Rb ratios from 214–281. When plotted on the Rb-(Y+Nb) tectonic discrimination plot of Pearce et al. (1984), these rocks plot in the Volcanic Arc Granite field (Fig. 5.26).

A differing trace element trend is present in some trachybasaltic, trachyandesitic, andesitic and dacitic minor intrusive rocks which cut the Ibáñez Formation. These rocks show similar patterns to the other minor intrusive rocks, with LIL enrichment and HFS depletion, including the Nb depletion spike. The basic samples plot as calc-alkali basalts whereas the more silicic samples plot in the volcanic arc granite field in the discrimination diagrams used above. However, these rocks also show a positive Sr enrichment peak and Y depletion. This Sr enrichment peak is mildly developed in two sills cutting the Ibáñez Formation at Maitén and Peninsula Ibáñez, but there is no noticeable Y depletion. Sr enrichment is well developed in a diverse group of basaltic trachy-andesitic, andesitic and dacitic sills, dikes and stocks which intrude throughout the Ibáñez Formation which show

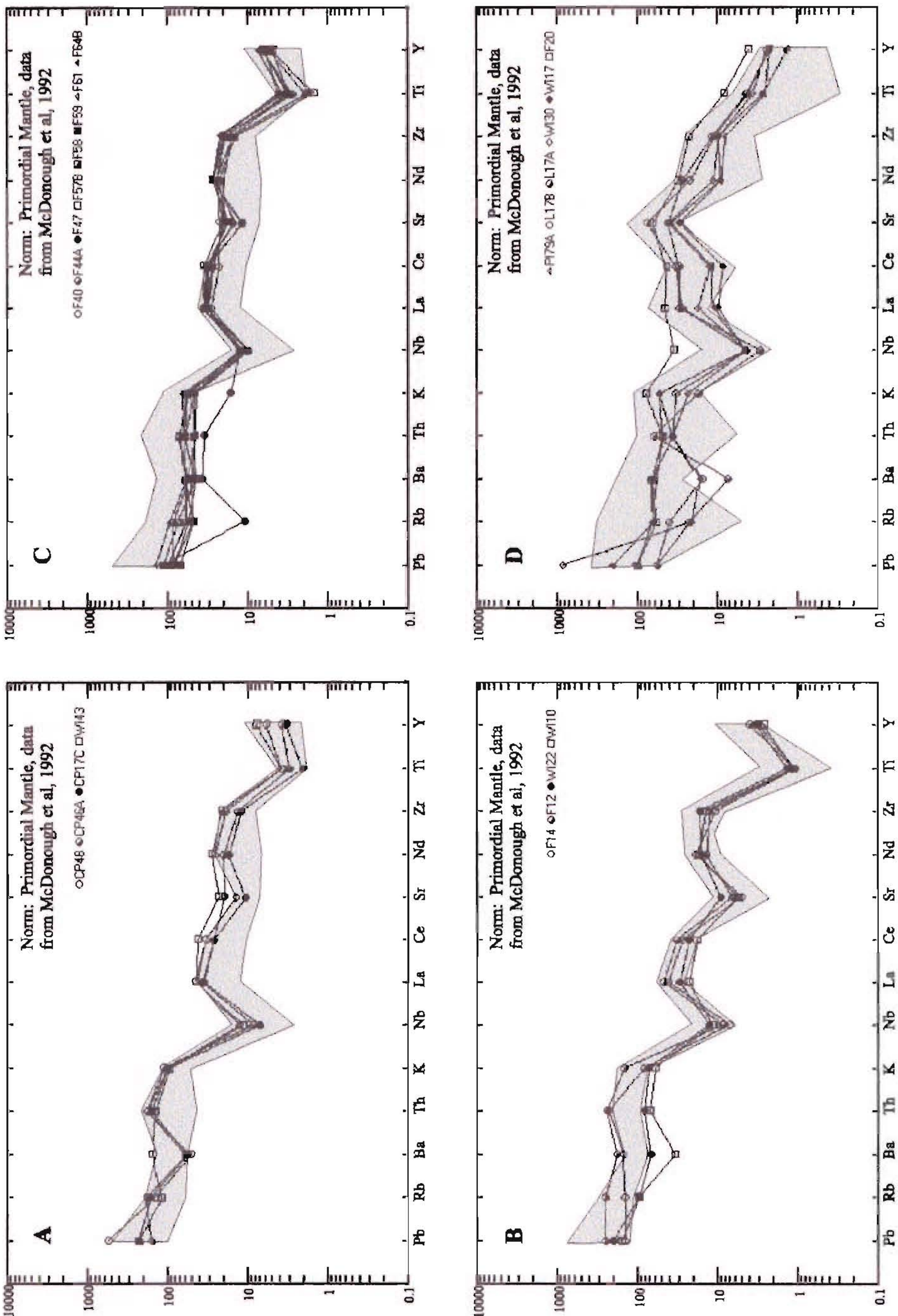


Figure 5.25: A) Trace element spider plot for dacitic dikes cutting the Ibáñez Formation at Cerro Pirámide (CP17-48) and Puerto Rey (WI 43). All samples in A) have LOI above 3%.
B) Trace element spider plot for rhyolitic dikes and sills cutting the Ibáñez Formation at Cerro Cabeza Blanca (F12-14) and Maitén (WI 10-22). Sample F12 has LOI above 3%.
C) Trace element spider plot for dacitic and rhyodacitic stocks and dikes cutting the Ibáñez Formation at La Pedregasa (F57-61), and the Coyhaique Group and Divisadero Formation between La Pedregasa and Estancia Moroma (F40-47, F64B). Samples F44A,F47,F57B and F59 have LOI above 3%.
D) Trace element spider plot for basaltic trachy-andesitic, andesitic and dacitic dikes, sills and stocks cutting the Ibáñez Formation at Cerro Pirámide (PI79), Peninsula Levicán (L17'), east of El Maitén (WI17), Puerto Rey (WI30) and Peninsula Ibáñez (F20), which show both Sr enrichment and Y depletion. Samples PI79A,L17B,WI17 and F20 have LOI above 3%.

Shaded fields indicate trace element ranges for dacitic (A and C) and rhyolitic (B) rocks from Taupo Volcanic Zone, New Zealand, for comparison. Data from Burt (1999), pers. comm. Shaded field in D marks trace element ranges of adakitic granite and granodiorite from Separation Point Batholith, New Zealand, for comparison. Data from Muir et al. (1995).

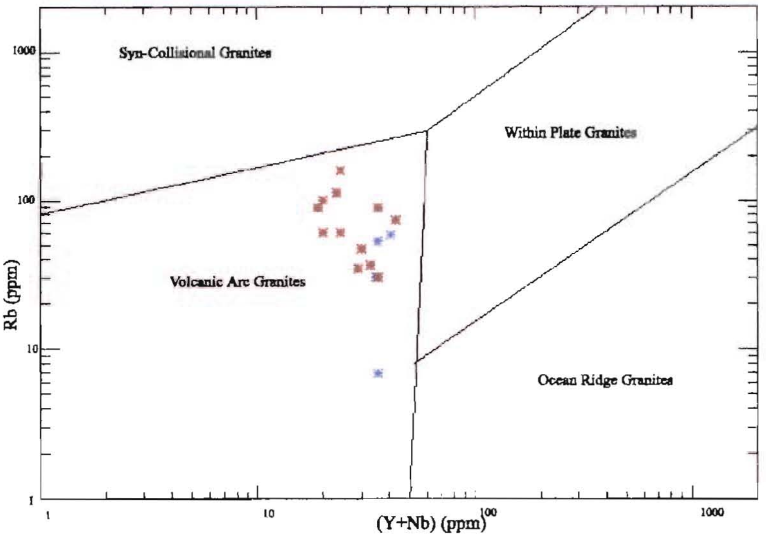


Figure 5.26: Rb vs (Y+Nb) granitoid discrimination plot for dacitic, trachy-dacitic and rhyolitic minor intrusive rocks, after Pearce et al. (1984).

both the Sr peak and Y depletion (Fig. 5.25D). These rocks otherwise show some scatter in LIL elements, particularly in depletion of Rb and Ba in three samples, but the Nb and Ti depletion spikes are of a similar pattern to those found in the remainder of the calc-alkaline and trachybasaltic to trachyandesitic rocks described above.

The strongly alkaline rocks, a mugearite stock cutting the Divisadero Formation, a mugearite dike cutting the Ibáñez Formation and the phonolitic sill cutting the Ibáñez Formation, show distinctly different patterns from the calc-alkaline and alkaline minor intrusive rocks. The mugearites (Fig. 5.27A) both show relatively flat patterns without LIL enrichment and with only mild HFS depletion. Neither sample shows any depletion of Nb or Ti. The phonolite sill from the Peninsula Ibáñez shows a very evolved pattern, without strong LIL enrichment and with moderate HFS depletion, but strong depletion of Ba, Sr and Ti. Nb depletion is absent (Fig. 5.27B). When compared to the mugearites (Fig. 5.27 C), the phonolite is a more evolved version of a similar trace element pattern, with strong depletions in Ba, Sr and Ti, and a positive Zr spike. The phonolite also compares well with the peralkaline rocks of Cerro Pico Rojo (compare Figs. 5.16A and 5.27B), showing an almost identical trace element distribution. The mugearites have Rb/Sr ratios of 0.05 and K/Rb ratios of 415 and 455, whereas the phonolite is more evolved with Rb/Sr ratio of 20 and K/Rb of 340. The mugearites plot as within-plate basalts, while the phonolite plots as a within-plate granite (Fig.5.28).

5.7 Granitoids and Microgranitoids

Granitic rocks occur as minor stocks, dikes and sills within and cutting both the Divisadero and Ibáñez Formations, and as massive subvolcanic stocks or ring structures at Cerro Pirámide and Cerro Farellón. Twenty eight samples were analysed, eleven from Cerro Farellón, seven from Cerro Pirámide, seven from minor stocks and sills, and two batholith samples, from Lago Esmeralda and Lago Bertrand. These rocks plot as subalkaline on a TAS diagram, within the calc-alkaline trend. The bulk of samples plot within the andesite to dacite fields, with outliers plotting as basaltic andesite or rhyolite, and altered samples and basic enclaves plotting as trachy-andesites or basaltic trachy andesites. On the TAS diagram of Wilson (1989), these rocks plot as granodiorites, some diorite and granite, with altered samples or basic enclaves plotting as syeno-diorites. All of these rocks are metaluminous (Fig. 5.29).

5.7.1 Major Elements

These rocks are quartz-hypersthene normative, and range from 52.7–69.9% SiO_2. Most samples plot as medium K. Harker variation diagrams (Fig. 5.30 and 5.31) show a clear trend with CaO, TiO_2, Fe_2O_3, MnO and MgO decreasing with increasing SiO_2, slight decrease in Al_2O_3 and slight increasing trends of K_2O and Na_2O. The granodioritic samples from the stocks at Cerro Pirámide, Cerro Farellón, Puerto Ibáñez and West Ibáñez plot as a linear trend, whereas the South Cerro Pirámide Diorites and dioritic samples from the other stocks plot as a loose cluster on a similar gradient but at a lesser SiO_2 content.

5.7.2 Trace Elements

Trace element plots for all the granitic rocks are shown in Fig. 5.32 and 5.33. The large stocks at Cerro Farellón, one sample from Cerro Pirámide (CP60, a sill) and the smaller

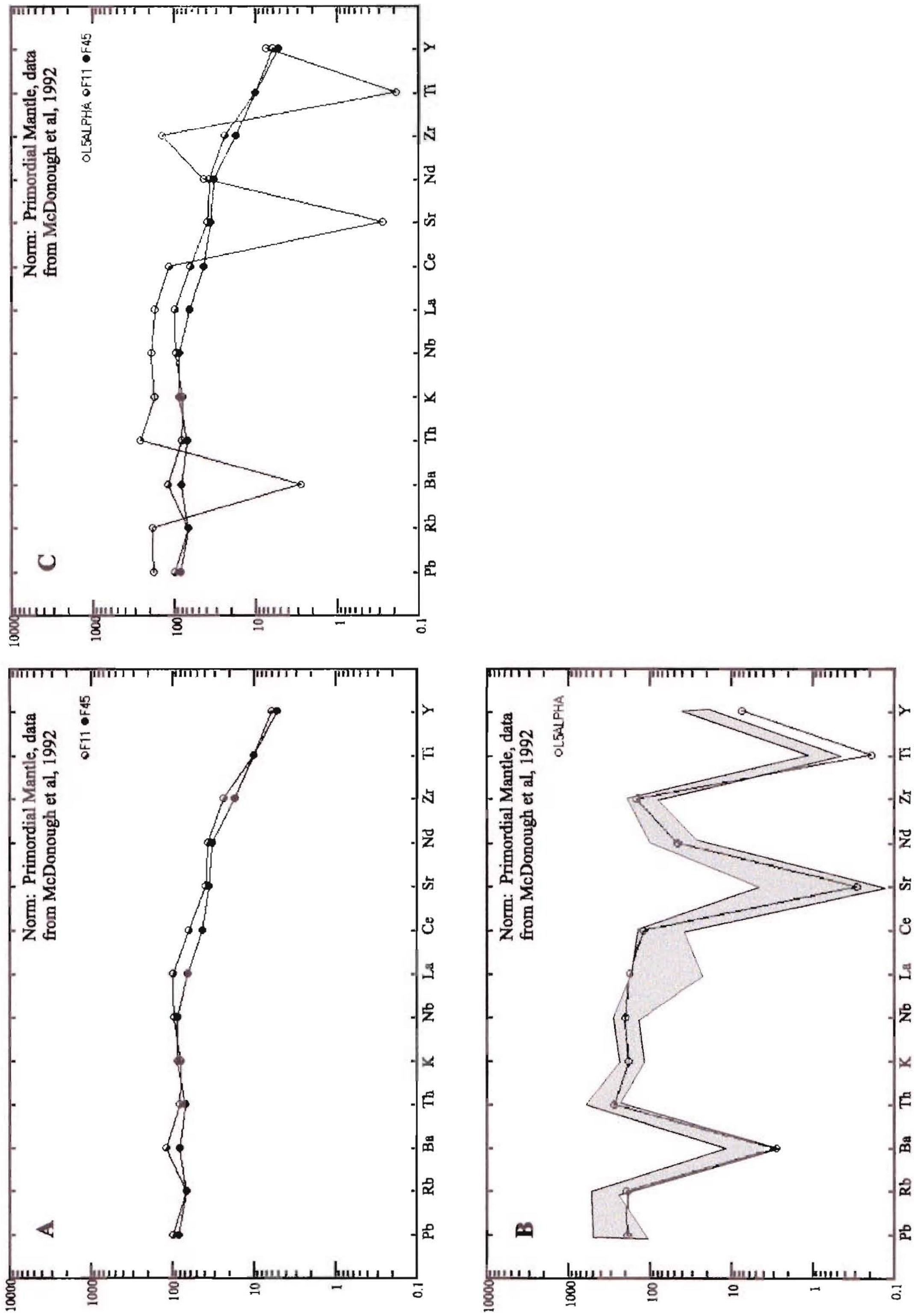


Figure 5.27: A) Trace element spider plot for mugearitic minor intrusive rocks cutting the Divisadero Formation at Estancia Moroma (F45) and the Ibáñez Formation at Peninsula Ibáñez (F11).
B) Trace element spider plot for the phonolitic sill cutting the Ibáñez Formation at Peninsula Levicán.
C) Trace element spider plot comparing the mugearites from A) with the phonolite plotted in B). All samples in A), B), and C) have LOI above 3%. Shaded field indicates trace element ranges for the peralkaline rhyolite at Cerro Pico Rojo (Fig. 5.16A).

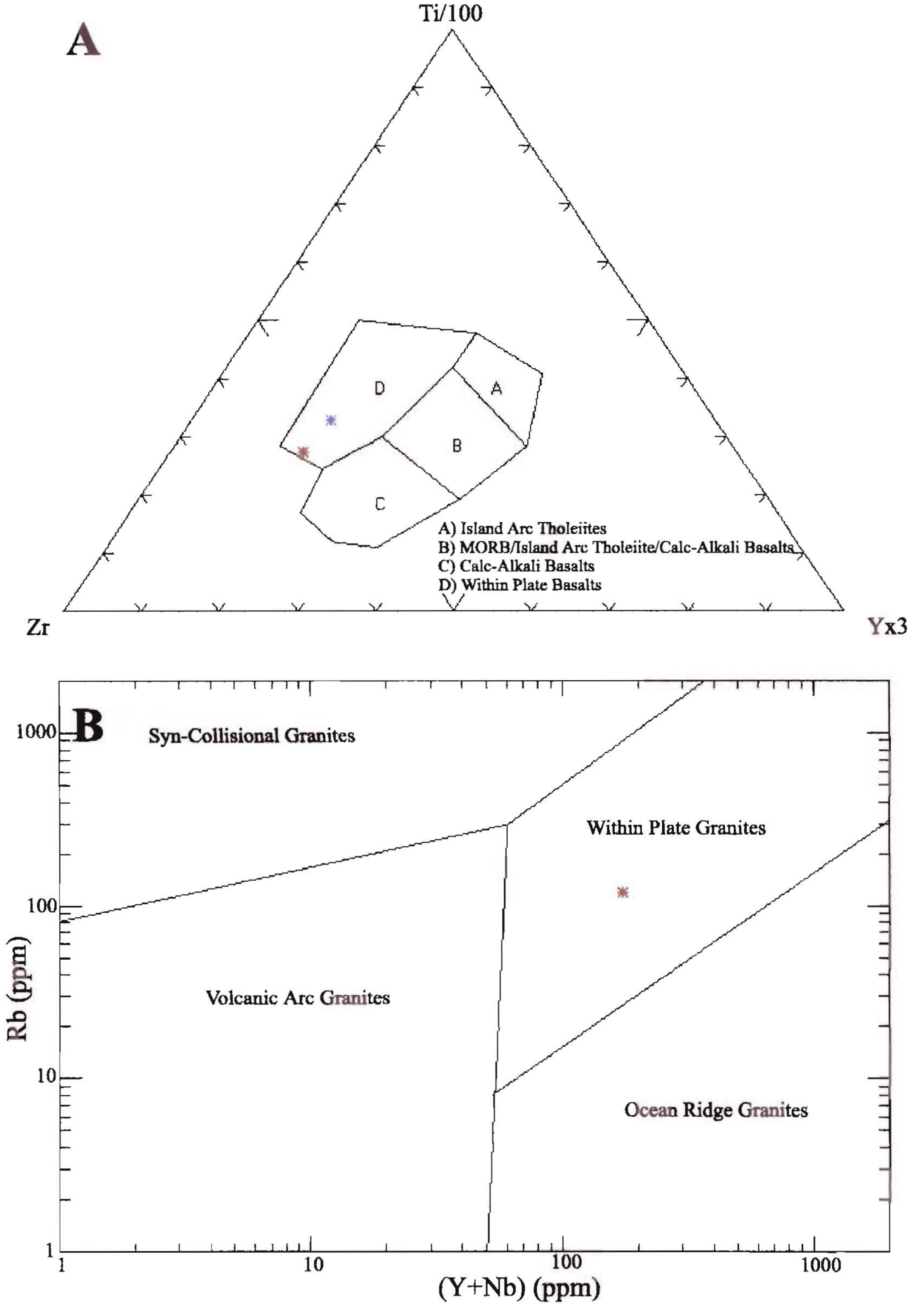


Figure 5.28: A) Mugearitic minor intrusive rocks plotted on a Zr-Ti-Y tectonic discrimination plot, after Pearce and Cann (1973).
B) L5α phonolite sample plotted on a Rb vs (Y+Nb) granitoid discrimination plot, after Pearce et al. (1984).

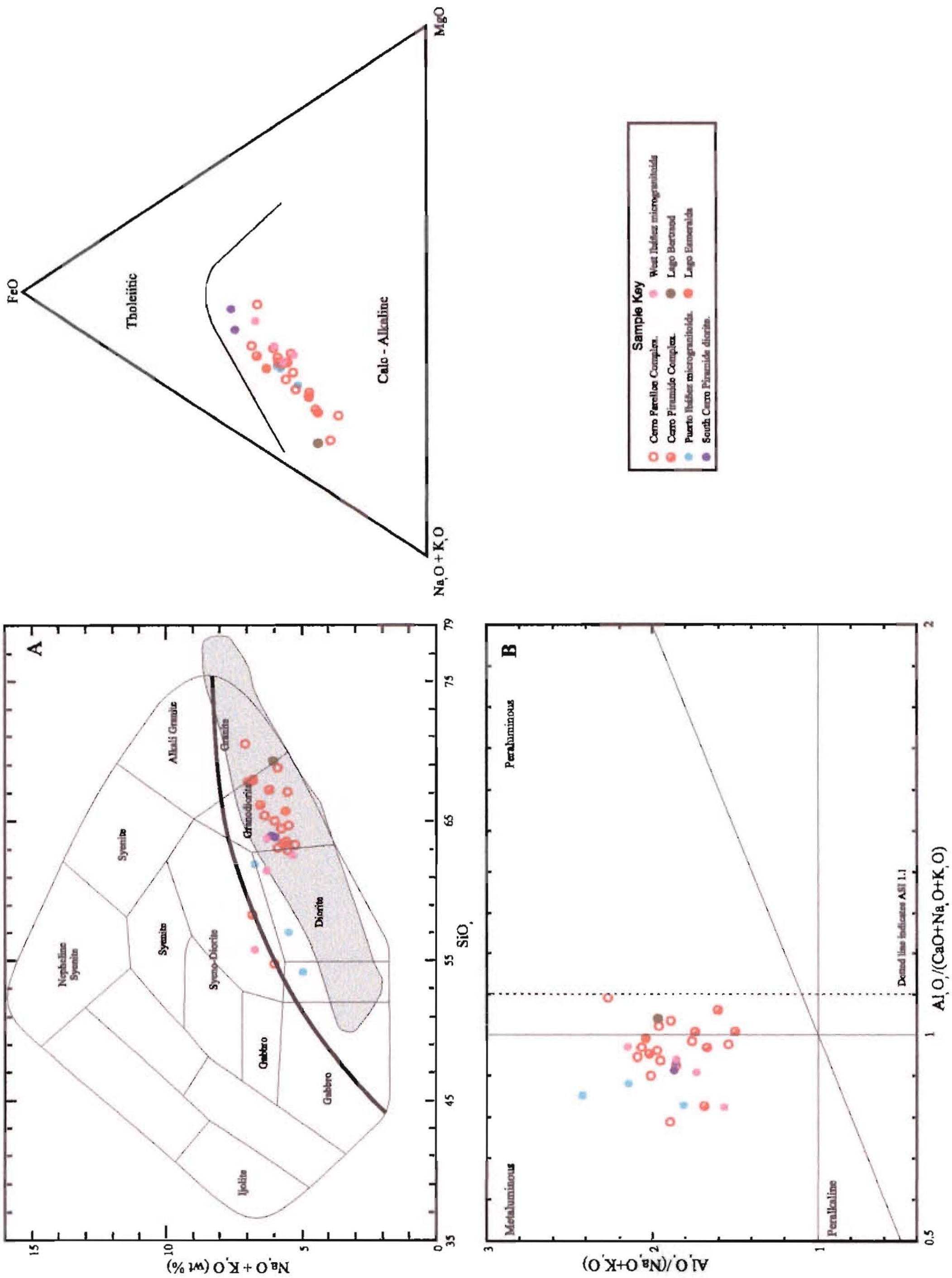


Figure 5.29: A) TAS plot for plutonic rocks in the Ibáñez Quadrangle and two samples of the Patagonian batholith from Lago Bertrand and Lago Esmeralda, after Wilson (1989). Data for the overlay field is from granitoid xenoliths from the Taupo Volcanic Zone, New Zealand. (Data from Burt (1999). Note that the West Ibáñez Granitoid samples (pink) have LOI greater than 3%.)
B) AFM plot for plutonic rocks in the Ibáñez Quadrangle and two samples of the Patagonian batholith from Lago Bertrand and Lago Esmeralda, after Irvine and Barragar (1971). Note that the West Ibáñez Granitoid samples (pink) have LOI greater than 3%.
C) ASI plot for plutonic rocks in the Ibáñez Quadrangle and two samples of the Patagonian batholith from Lago Bertrand and Lago Esmeralda, after Maniar and Piccoli (1989). Note that the West Ibáñez Granitoid samples (pink) have LOI greater than 3%.

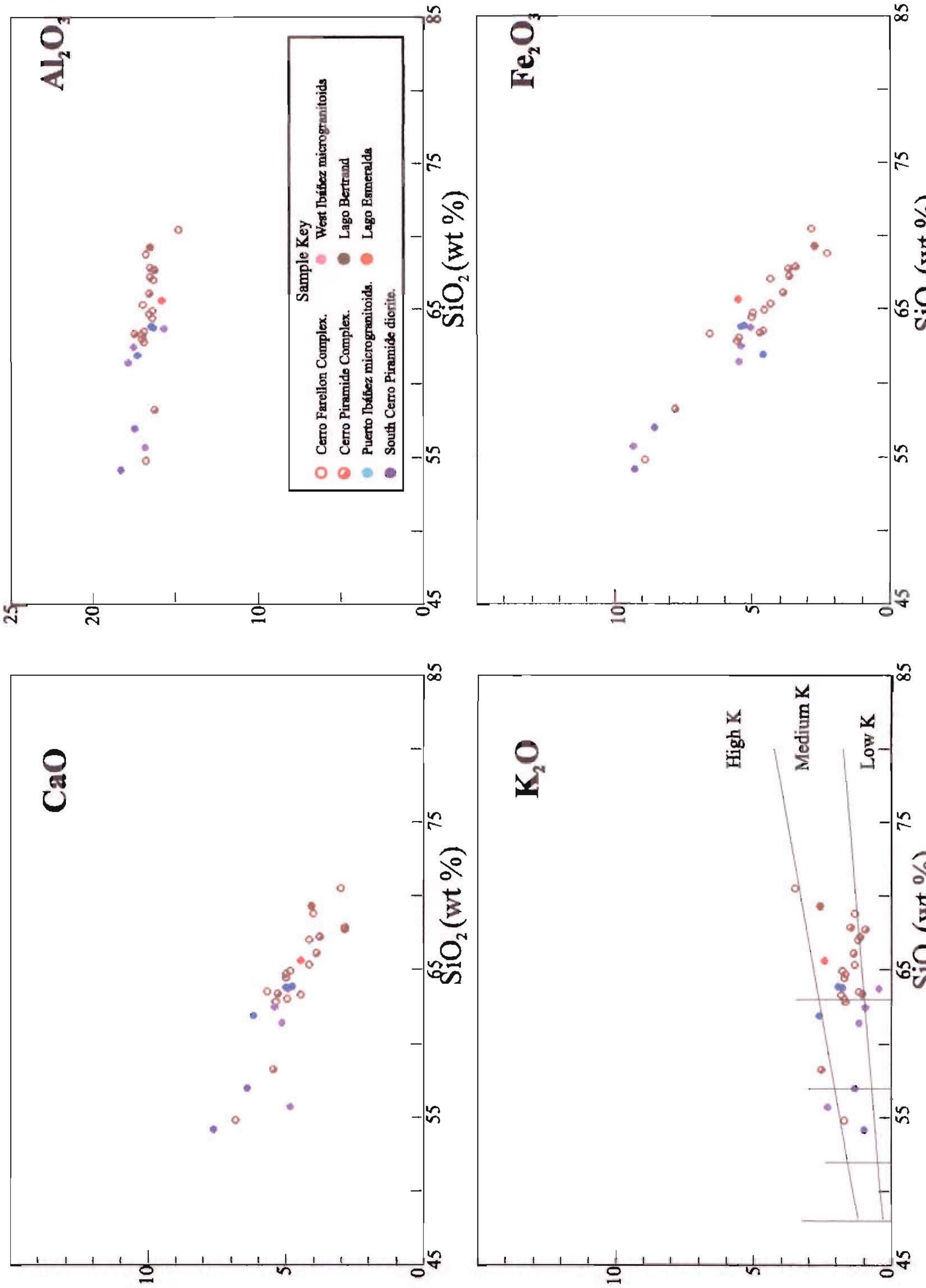


Figure 5.30: Harker variation diagrams for major elements of granitoid and microgranitoid samples from the Ibáñez Quadrangle, Lago Bertrand and Lago Esmeralda. Fields in K_2O plot after Le Maitre (1989). Note that the West Ibáñez Granitoid samples (pink) have LOI greater than 3%.

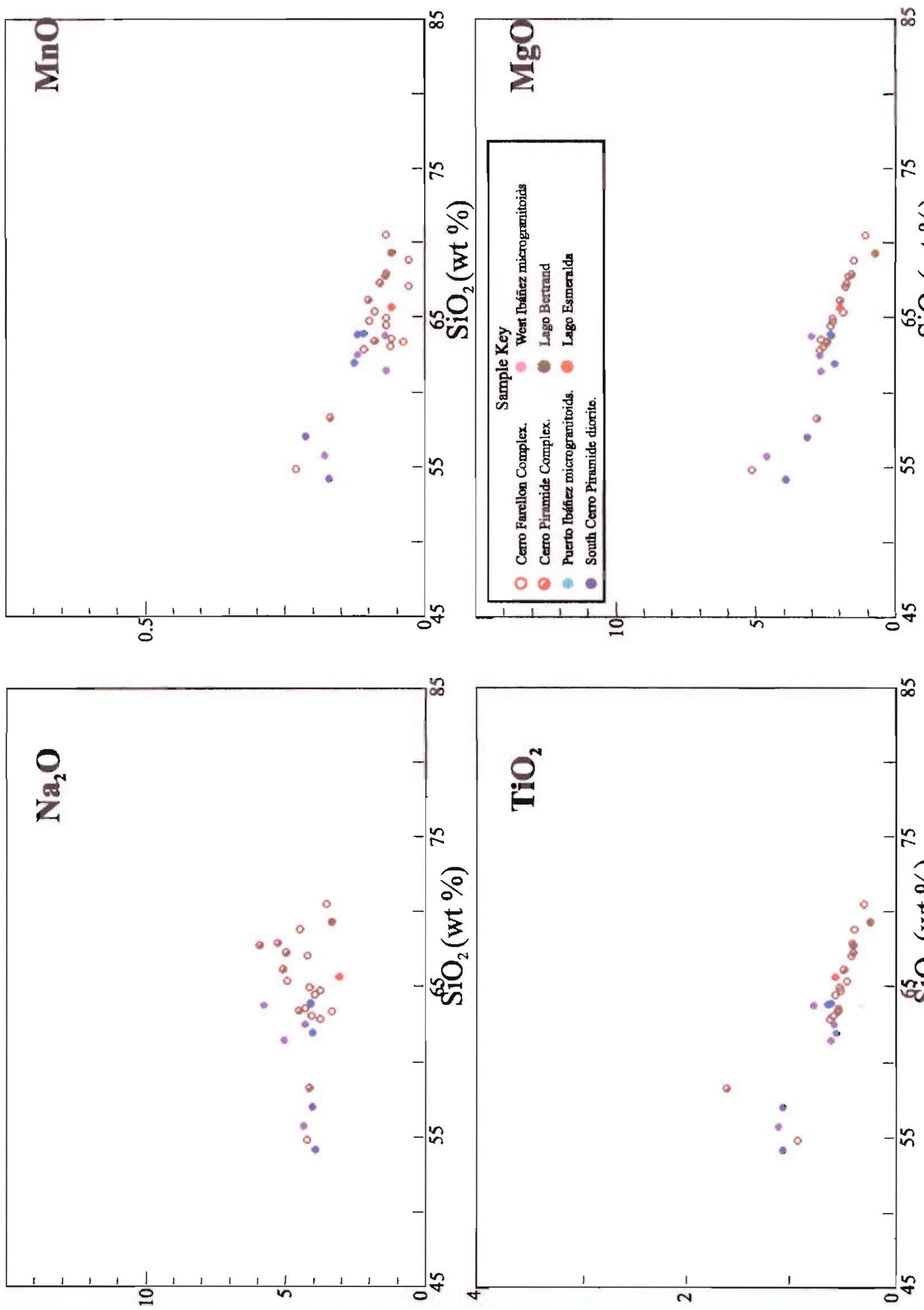


Figure 5.31: Harker variation diagrams for major elements of granitoid and microgranitoid samples from the Ibáñez Quadrangle, Lago Bertrand and Lago Esmeralda. Note that the West Ibáñez Granitoid samples (pink) have LOI greater than 3%.

granitic stocks and sills at Puerto Ibáñez, Puerto Rey and South Cerro Pirámide (see Figs. 5.32A, C and D, 5.33A and B) generally show similar trace element trends to those of the andesitic to dacitic rocks of the Ibáñez Formation and the minor intrusive rocks, with moderate LIL enrichment and HFS depletion, and depletion spikes at Nb and Ti. Some samples have slight Sr depletion, but are without the stronger Sr depletion spike pattern found in the rhyolitic rocks of either the Ibáñez or Divisadero Formations. A similar pattern is present in the two samples from the Patagonian Batholith, at Lago Bertrand and Lago Esmeralda, both of which show a similar LIL enrichment/HFS depletion pattern with depletion spikes of Nb and Ti, and slight depletion of Sr. However, five samples from the Cerro Farellón complex show a different trace element distribution, with a mild Sr enrichment spike, and depletion in La as well as Nb and Ti (Fig. 5.32B), and the remaining five granodioritic samples from Cerro Pirámide also show Sr enrichment (Fig 5.32C). Two granodioritic samples from the West Ibáñez microgranitoids, specifically those at Maitén, have Nb and La depletion and less enrichment of LIL elements, and show mild Sr enrichment (Fig. 5.33B), similar to some Cerro Farellón complex samples in Fig. 5.32B. The granitic rocks have Rb/Sr ratios from 0.02–0.54, and K/Rb ratios from 162–404, with all samples but one plotting within the Volcanic Arc Granite field on the Rb vs (Y+Nb) diagram of Pearce et al. (1984) (Fig. 5.33D). One sample from Cerro Pirámide plots on the field border between volcanic arc granites and within plate granites, and in particular this sample (CP 60)was also the only Cerro Pirámide sample to plot a slightly more enriched trace element pattern to the remaining Cerro Pirámide samples, and it was also without Sr enrichment (see Fig. 5.32C).

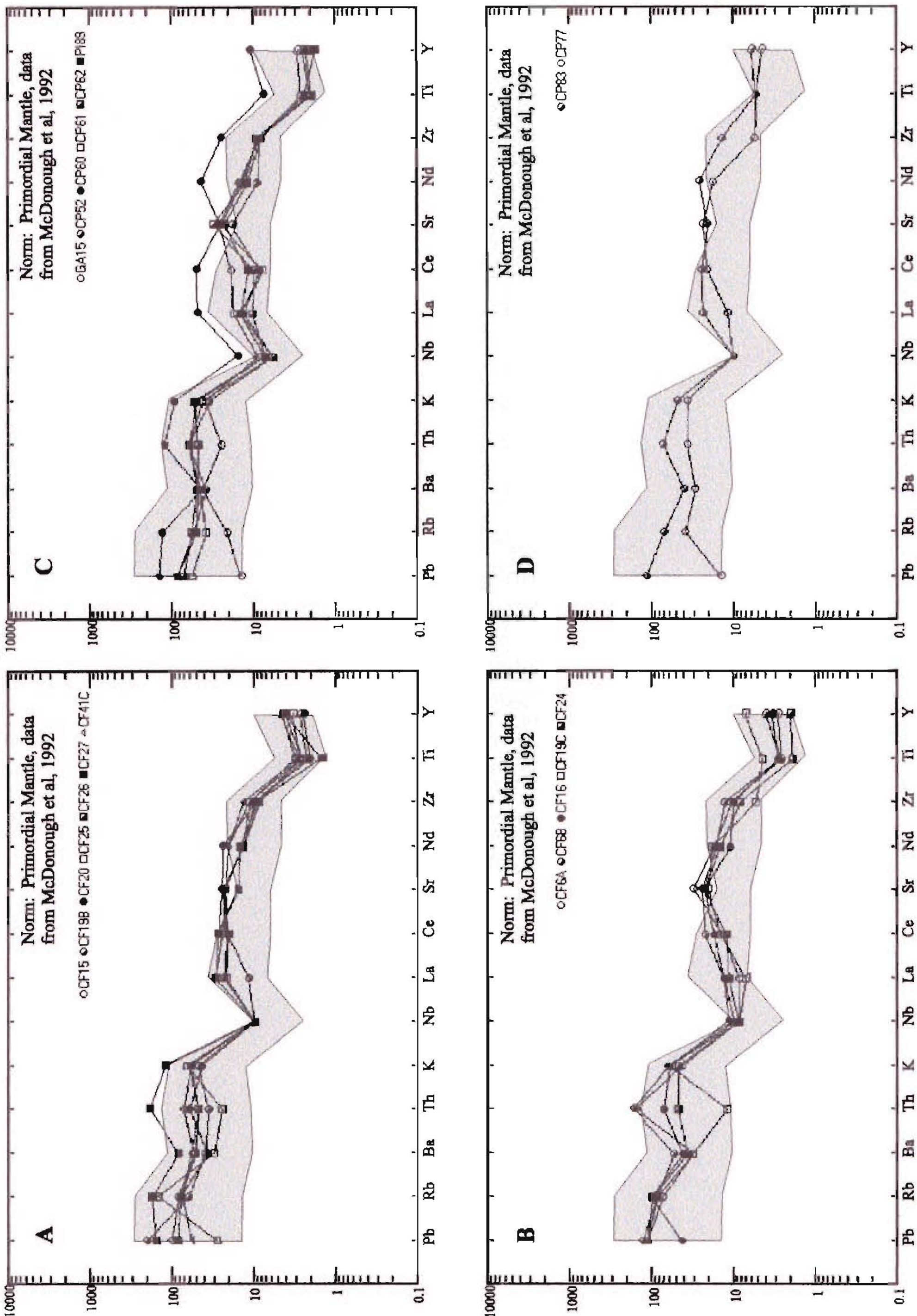


Figure 5.32: A) Trace element spider plot for the Cerro Farellón Microgranitoid complex, showing HFS depletion, LIL enrichment, with depletion spikes at Nb and Ti.

B) Trace element spider plot for the Cerro Farellón Microgranitoid complex, showing HFS depletion, LIL enrichment, with variable Th, some Sr enrichment, and depletion of Nb, La and Ti.

C) Trace element spider plot for the Cerro Pirámide Microgranitoid complex, showing HFS depletion, relatively flat LIL enrichment, Sr enrichment . Sample CP 60 is from a diorite sill at the base of Cerro Pirámide and shows a more evolved pattern without Sr enrichment. All Cerro Pirámide samples show Nb and Ti depletion.

D) Trace element spider plot for the South Cerro Pirámide Diorites, showing LIL enrichment, HFS depletion, no Sr enrichment and depletion of Nb and Ti.

Shaded fields are for trace element ranges from diorite and granodiorite xenoliths from Taupo Volcanic Zone, NZ, for comparison. Data from Burt (1999).

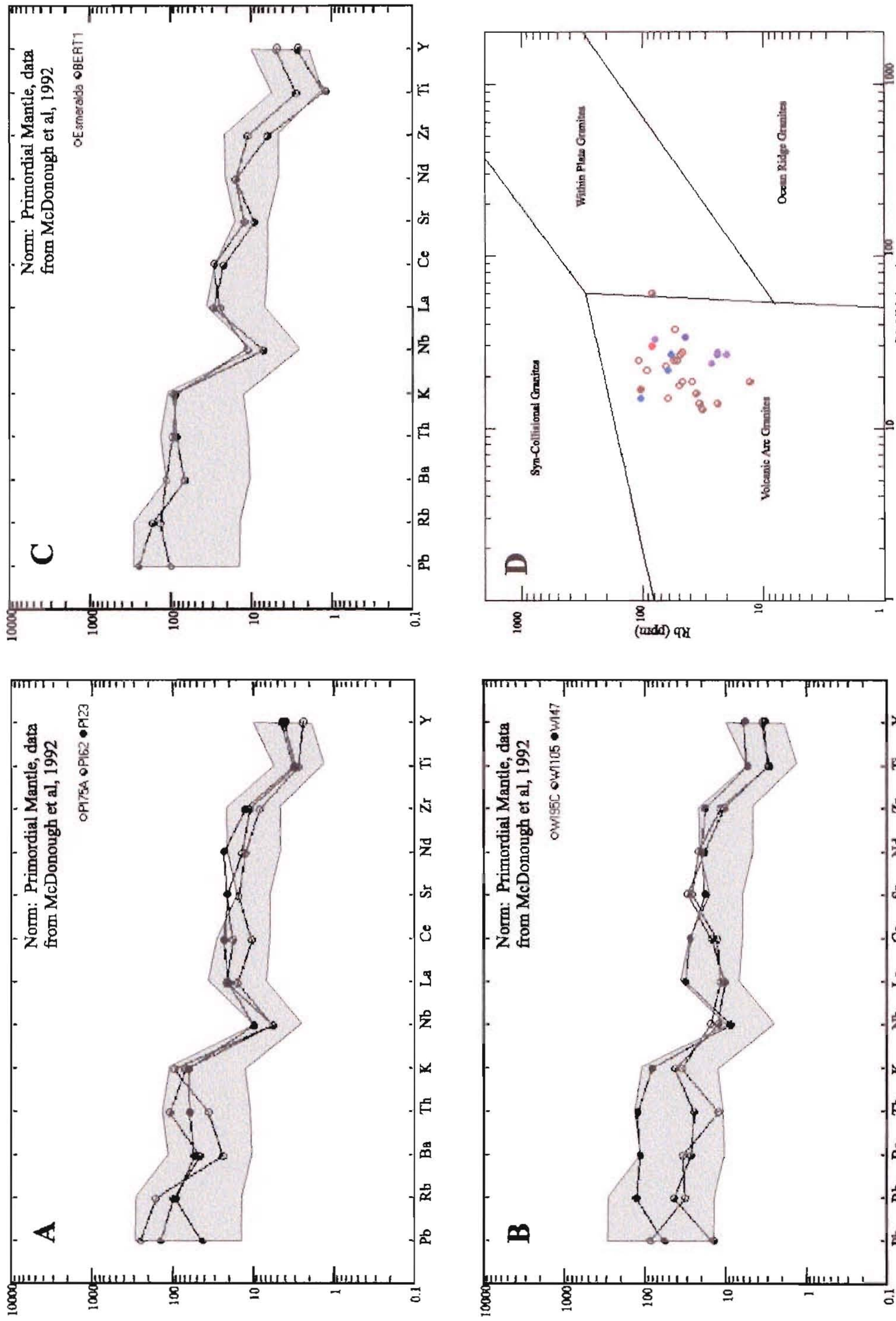


Figure 5.33: A) Trace element spider plot for the Puerto Ibáñez microgranitoids showing LIL enrichment and HFS depletion, with depletion in Nb and Ti.

B) Trace element spider plot for the West Ibáñez microgranitoids, showing two distinct trends, with one sample showing LIL enrichment and HFS depletion with Nb and Ti depletion spikes, and two samples showing less LIL enrichment, slight Nb and La depletion, Sr enrichment and Ti depletion.

C) Trace element spider plot for a granodiorite from Lago Esmeralda and granite from Lago Bertrand, showing similar patterns of LIL/HFS enrichment and depletion, and with depletion spikes at Nb, Ti and Sr.

D) Granitoids and microgranitoids from the Ibáñez Quadrangle, Lago Bertrand and Lago Esmeralda. plotted on the Rb/(Y+Nb) granite discrimination diagram of Pearce et al. (1984).

Note that sample PI75A and the West Ibáñez Granitoid samples have LOI greater than 3%.Shaded fields are for trace elements from Taupo Volcanic Zone diorite and granodiorite xenoliths for comparison. Data from Burt (1999), pers. comm.

Chapter 6

Age of the Mesozoic Rocks of the Puerto Ibáñez Area

6.1 Paleontology and Biostratigraphy

6.1.1 Ibáñez Formation

The Ibáñez Formation has no body fossils in the Puerto Ibáñez quadrangle and contains only some trace fossils, occasional wood fragments and leaf fossils (see Chapter 3). Sparse fossil ocurrences summarised in Skarmeta (1978) give a range of ages from Tithonian (Feruglio, 1944) to Berriasian (Leanza, 1967), whereas the presence of Berriasian faunas immediately overlying tuffaceous sediments tentatively identified as 'Complejo Porfirico' was reported at a location south of Ńirehuao (Charrier and Covacevich, 1980). Confirmation of the extension of the Ibáñez Formation into the lower Cretaceous is found at Lago Norte, some 200km north of the Puerto Ibáñez Quadrangle, (See Fig. 6.1) where a Berriasian fauna containing *Blanfordiceras spp* occurs (Covacevich et al., 1994).

Two sites at Lago Norte (GR 19278818 5006164 and 19279304 5005856) were sampled. Ammonite shell fragments collected match the description of *Blanfordiceras spp* given by Covacevich et al. (1994), and a sketch stratigraphic column was made at GR 19278818 5006164 from the fossiliferous strata through to the local top of the Ibáñez Formatio (see Figure 6.1). The ammonites are incomplete fragments, and occur in the thickly bedded basal sandstones of a fining upwards sequence of medium and coarse volcaniclastic sandstones that grade into fine muddy sandstones and laminated shales. With the ammonoids are oysters, scallops and robust bivalve shell fragments. The base of this 40m-thick sequence rests on weathered tuffaceous coarse sandstones containing some fossil fragments, and showing normal grading and internal "Bouma" sequence type mass flow structures, whereas the top of the fossiliferous sandstones and shales grades into thickly bedded tuffaceous coarse sandstones, above which are 60m of ignimbritic tuffs, followed by a fining upwards sequence of weathered purple ignimbritic tuffs and tuffaceous sandstones. The top of the section is massive, faulted and fractured rhyolitic tuffs and silicic tuffs, weathered and purple and overlain by andesitic breccias and lavas, in turn faulted against more lithic tuffs, and capped by a later andesitic sill. This sequence indicates a short, and probably fairly local, early phase of the Austral Basin marine transgression, possibly facilitated by rifting during late Ibáñez Formation eruption and sedimentation in the Late Jurassic and earliest Cretaceous (Gust et al., 1985; Suárez and de la Cruz, 1997a). The marine basin was initially infilled by volcaniclastic debris flow sandstones bearing transported and broken fossil fragments, then by a relatively quiescent period with deposition of fine sandstone, mudstone and shale, before a final infilling by rhyolitic volcaniclastic sandstones and renewed silicic volcanism supplying tuffs and tuffaceous sandstones (either sub-aqueous or sub-aerial). This infilling was followed by subaerial andesitic lavas, possibly representing remnants of stratovolcanoes (Covacevich et al., 1994).

6.1.2 Coyhaique Group

The Coyhaique Group units outcropping in the Ibáñez Quadrangle were thought by Skarmeta (1978) to be of Valanginian-Hauterivian age, based on the occurrence of *Favrella americana*. South of Lago General Carrera, a similar age was assigned by Charrier and Covacevich (1980). Suárez and de la Cruz (1994b) give a Hauterivian age based on ammonites for the Katterfeld Formation and the Apeleg Formation in the Coyhaique region, and Hauterivian-Aptian for the Apeleg Formation south of Lago General Carrera.

Within the Ibáñez Quadrangle and the southern Farellon Quadrangle, only one fossiliferous location was found within the Coyhaique group, with ammonites, bivalves, sharks teeth and saurian bones present in small limestone hardgrounds within the Katterfeld Formation below Cerro Manchón (see Chapter 3). Two species of ammonites occur, and are identified as belonging to *Crioceratites nolani/duvali* group (Aguirre-Urreta, 1998

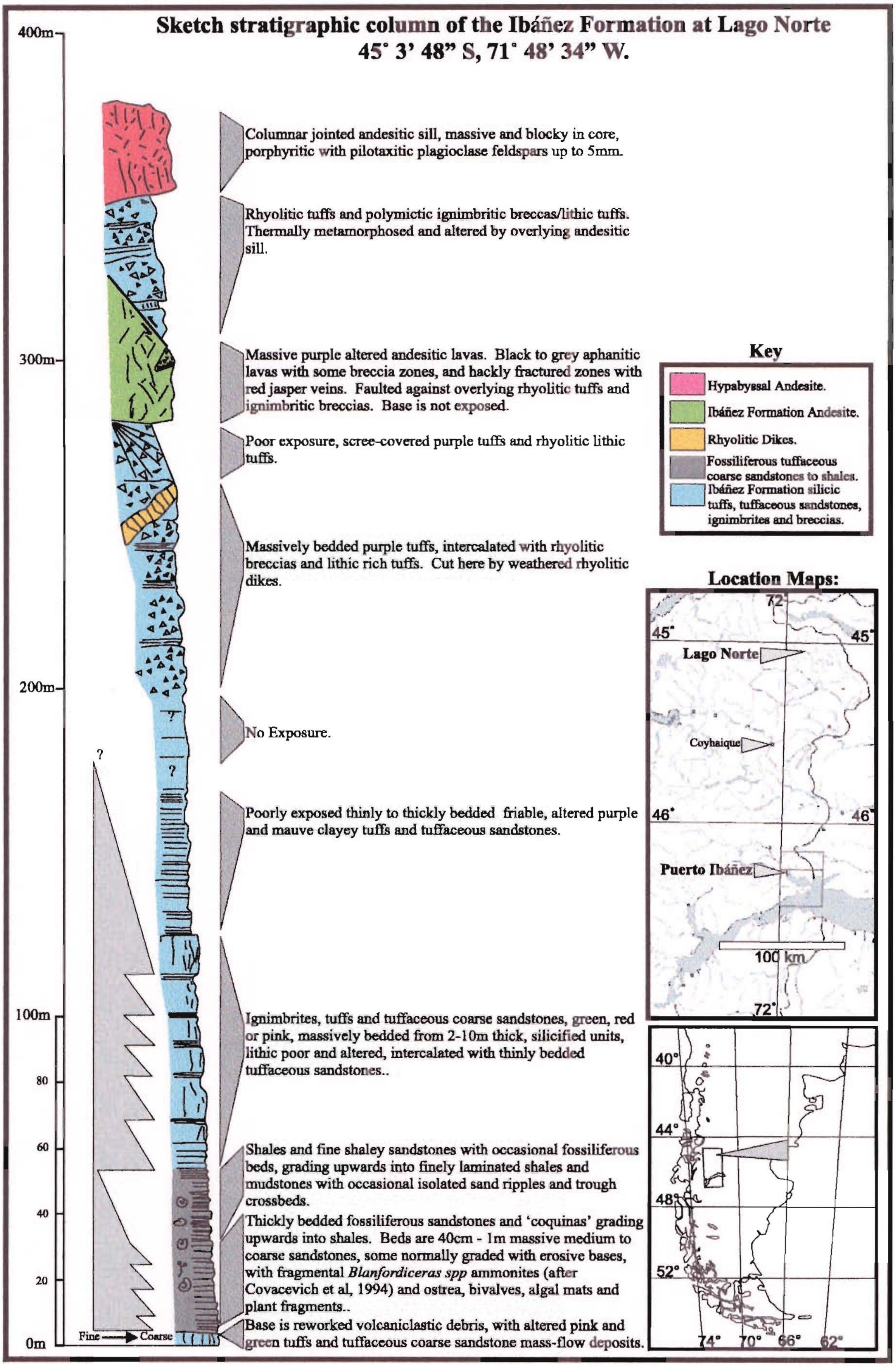


Figure 6.1: Sketch stratigraphic column of the Ibáñez Formation at Lago Norte.

a; Riccardi, 1988) and *Aegocrioceras* (Aguirre-Urreta, 1998 b) indicating a Hauterivian age for the Katterfeld Formation in the southern Farellon Quadrangle, matching the age of the Katterfeld formation in much of the Aysén region (Fig. 6.2). The *Crioceratites nolani/duvali* group has also been described from the upper member of the Agrio Formation in the Neuquen basin of North Patagonia, Argentina, with an upper Hauterivian age (Aguirre-Urreta, 1999). Both *Crioceratites nolani/duvali* and *Aegocrioceras* are known from the western Tethyan realm, with *Aegocrioceras* in particular known previously from the Speeton Clay in the UK and elsewhere in Northwest Europe, particularly in Germany (Aguirre-Urreta, 1998 b), suggesting seaway connections of both the Nuequen and Austral Basins with the Tethyan region (see Fig. 1.7), presumably by a proto-Atlantic seaway. The occurrence of *Crioceratites nolani/duvali* in both the Neuquen basin and the Austral basin is also significant, showing evidence of connection of these two basins with coeval faunas in the lower Cretaceous (Aguirre-Urreta et al., 2000). The Apeleg Formation has no body fossils but contains grazing and burrowing trace fossils, as well as wood fragments and occasional logs in its upper parts, particularly near the gradational contact with the Divisadero Formation.

6.1.3 Divisadero Formation

No body fossils were found within the Divisadero Formation in either the Ibáñez Quadrangle or the measured sections taken in the Coyhaique region, except as small fragments of wood or bone at the cores of oncoliths in allocthonous oncoid limestone blocks from slump deposits in redbeds at Cerro Manchón, and stromatalitic algal limestone in lithic blocks at the Cerro Montreal section. These oncoliths, with a core of rock, bone, wood or other organic matter, covered with laminae of calcified cyanobacteria sheaths with radial crystalline or bushy structures, are indicative of freshwater lacustrine or fluvial environments (Riding, 1990).

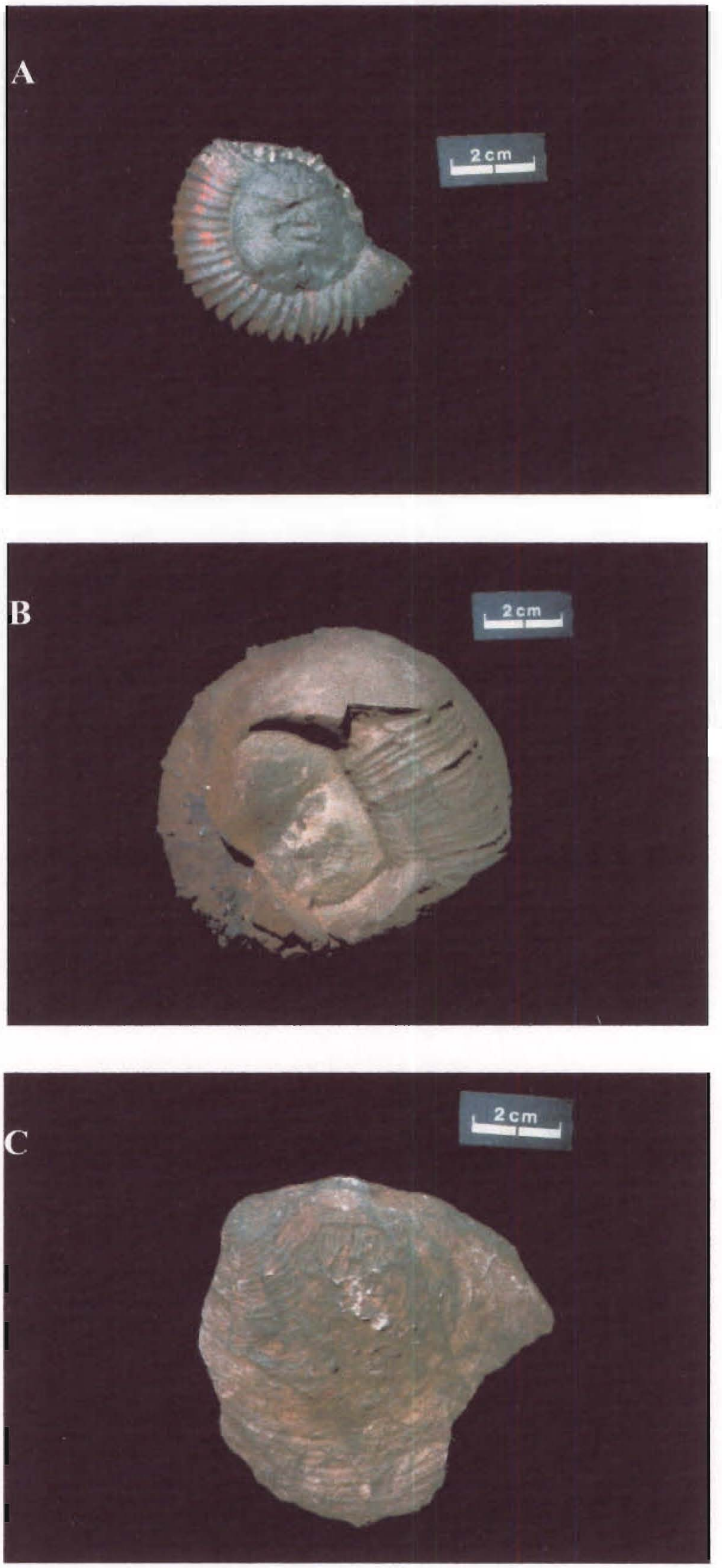


Figure 6.2: Ammonoid and bivalve fossils from the Katterfeld Formation southwest of Cerro Farellón, from fossiliferous hardgrounds within the blocks of Katterfeld Formation blackshales which have been moved by the landslide below Cerro Manchón. A) *Aegocrioceras* B) *Crioceratites nolani/duvali* group and C) *Inoceramid* bivalve. Specimens kindly identified by Beatriz Aguirre-Urreta, Buenos Aires, (Aguirre-Urreta, 1998 b).

6.2 Ar-Ar Radiometric Dating

Eight samples were processed for 40Ar/39Ar radiometric dating. Results are given in Appendix D and in Table 6.1, and compared with other radiometric data for the Ibáñez Formation and related rocks in Patagonia. The samples were analysed in 1999 at the Institute of Geological & Nuclear Sciences, Lower Hutt, New Zealand, at their Ar-Ar facility, by Dr Chris Adams. Samples were step heated in ninr steps of 100°C each from 550-1450°C. With some samples, only four or five steps were possible before the argon content was exhausted. Precision was reduced because of some excess argon from the copper foil packaging in which the samples were irradiated, excess argon released in the early heating steps, and also by a mistake in the irradiation process, when the reactor technicians misread the requested 72 hours as 12 hours and only irradiated the samples for the shorter period. The analyses were calibrated against the American LP6 biotite standard (127Ma) (Adams, 1999).

6.3 Summary

6.3.1 Ibáñez Formation

Three samples of the Ibáñez Formation in the Puerto Ibáñez Quadrangle were analysed: biotite separates from an ignimbrite and a rhyolite, and muscovite from an ignimbrite. The muscovite sample from sericitised pumice fiamme in an ignimbrite at Peninsula Ibáñez gave 151.8±6.2 Ma, which can be interpreted as a Late Jurassic alteration age dating the formation of the muscovite replacing the pumices, indicating that the ignimbrite itself is probably older. The Cerro Cabeza Blanca rhyolite which intrudes through and overlies the andesites, tuffs and ignimbrites of the Peninsula Ibáñez yielded biotite which gave an date of 150.3±1.8 Ma, slightly younger than the tuffs beneath but statistically the same within the error margins. This rhyolite dome has previously been mapped as Upper Cretaceous or Tertiary (Skarmeta, 1978). K-Ar analysis was also carried out on biotite from the Cerro Cabeza Blanca rhyolite, and returned a date of 155±2.8 Ma. These two dates are from fresh biotite phenocrysts, and may bë interpreted as close to the actual crystallisation age, giving the dome a probable eruption age between 150-155Ma. The underlying andesites, ignimbrites and tuffaceous sediments of the Peninsula Ibáñez are therefore probably older than 155 Ma, and have undergone a thermal alteration with sericitisation of pumice fragments at 151 Ma. The third Ar-Ar analysis for the Ibáñez Formation on biotite from an ignimbrite on Peninsula Levicán gives 143.4±2.1 Ma. The biotite occurs as fresh crystal fragments within the upper part of a welded and columnar jointed ignimbrite, and could be interpreted as representing a crystallisation age predating the eruption of the ignimbrite. This may indicate a Tithonian to Berriasian age for ignimbrites on the Peninsula Ibáñez. However, biotite collected from an ignimbrite within 1km of this location has returned a K-Ar date of 150±4Ma (Suárez and de la Cruz, 1997b), whereas Pankhurst et al. (2000) report a U-Pb SHRIMP isochron age for a sample from this locality of 153.0±1.0Ma, indicating that the younger date from this study may be a result of analytical error, or may indicate that a thermal event has 're-set' the sample, giving a cooling age in the Lower Cretaceous or later.

Although processing and analytical errors in the analysis of these samples must be taken into account, the resulting age range for the Ibáñez Formation of the Puerto Ibáñez Quadrangle is 150.3±1.8–155±2.8 Ma, with possible thermal events causing alteration and re-setting of Ar-bearing minerals between 151–143 Ma. The dates acquired compare well with the paleontological information summarised above and with previously published data for the Ibáñez Formation at Chile Chico immediately south of Lago General Carrera and the El Quemado Formation further south in the Provincia de Santa Cruz, Argentina (Suárez and de la Cruz, 1997a,b) (See also table 6.1 and Fig 6.3). They are older than the 136±3 Ma K-Ar date for the Ibáñez Formation given by Charrier et al. (1978), which may be thermally re-set. These new dates are also significantly younger than Rb-Sr isochron ages published for both the Chon Aike Formation and the Marifil Complex, although still older than the Cretaceous Rb-Sr isochron age for the El Quemado complex, though this is thought to have been thermally re-set by Cretaceous activity in the North

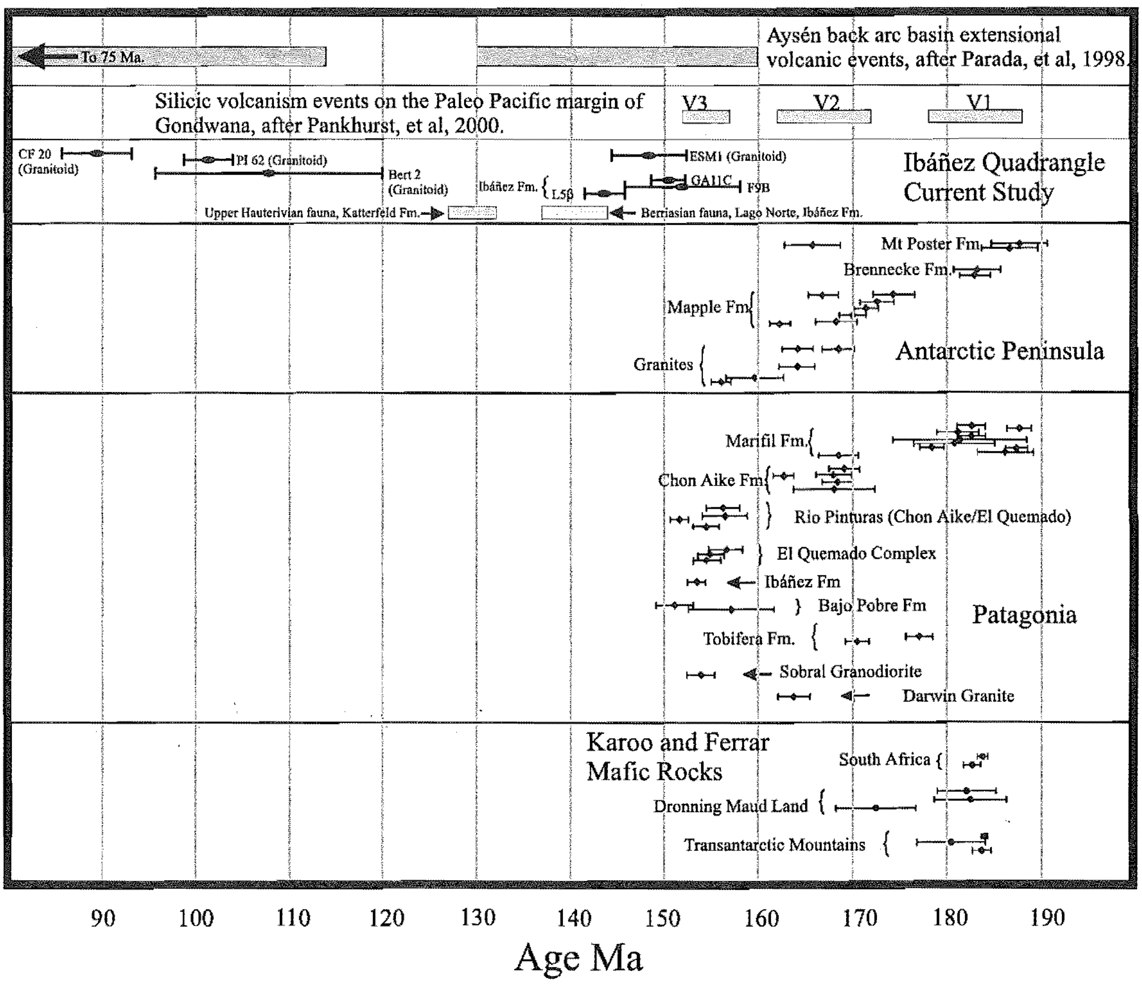


Figure 6.3: Comparison chart of Ar-Ar and fossil age data from the Ibáñez Quadrangle, Lago Bertrand, Lago Esmeralda and Lago Norte with U-Pb SHRIMP and Ar-Ar data from Pankhurst et al. (2000). Also shown are the Aysén Basin extensional back arc volcanic events of Parada et al. (2001), and the Gondwana Margin V1-V3 silicic volcanic events of Pankhurst et al. (2000); Riley et al. (2001).

Patagonian Batholith (Pankhurst et al., 1993; Rapela and Pankhurst, 1993). An age of 155 Ma for rocks of the Tobifera Formation south of 50 degrees was calculated by Halpern (1973), based on bulk Rb/Sr ratios, which roughly correlates with the Ar-Ar ages in this study. However, Pankhurst et al. (2000) give robust ages of 171 –178 Ma for the Tobifera Formation from U-Pb SHRIMP analyses, so the Ibáñez Formation is significantly younger than the Tobifera.

These data support the hypothesis that Jurassic silicic volcanism in Patagonia youngs to the southward (Rapela and Pankhurst, 1993), and it may also be noted that the Ibáñez Formation and the cognate El Quemado Complex form a westwards-younging extension of this trend. Also based on these data and previously published ages, the Ibáñez Formation can be included as part of the youngest Patagonian episode of Jurassic silicic volcanism (V3) as defined by Pankhurst et al. (2000), although the youngest ages from both radiometric and fossil data may require extension of the 'V3' event into the Berriasian. These data also fit the Ibáñez Formation within the earliest of the three main Mesozoic back arc extensional events of the Aysén region as defined by Parada et al. (2001), from 160–130 Ma (see Fig. 6.3).

6.3.2 Divisadero Formation

One sample from the Divisadero Formation at Cerro Divisadero near Coyhaique was analysed. Biotite crystal fragments from a vitric tuff near the mid-point of the measured section taken at Cerro Divisadero returned a date of 138±4.9 Ma, a Berriasian-Valanginian age, but this date is at odds with the biostratigraphy of the underlying Coyhaique Group, which as discussed above ranges from the Hauterivian to the Aptian. The Divisadero Formation to the north of Coyhaique at Bano Nuevo is Hauterivian, whereas K-Ar dates of 102±3 Ma from Cerro Divisadero at Coyhaique and 111±2 Ma from Meseta Buenos Aires south of Lago General Carrera (Suárez and de la Cruz, 1994b) place it as Albian in age. The date of 138±4.9 Ma returned from Cerro Divisadero is therefore too old, probably due to excess argon, and must be discarded. The Divisadero Formation at Cerro Divisadero thus remains at Albian, while the Divisadero Formation outcropping in the Puerto Ibáñez Quadrangle is probably Aptian to Albian.

6.3.3 Granitoids

Four samples from granitoids were analysed, two granodiorite samples from the Puerto Ibáñez quadrangle, a granodiorite from Lago Esmeralda and a granite from Lago Bertrand, with results given in Table 6.1. An additional K-Ar analysis for Lago Esmeralda gave 147±3.4 Ma. The Puerto Ibáñez granodiorite and the Lago Bertrand granite at 101 and 107 Ma correlate well with K-Ar ages of 100–128Ma for plutons in the Aysén region associated with subduction and the development of the Estero Los Flamencos Tuffs and the Divisadero Formation (Suárez and de la Cruz, 1997a), whereas the date of 89.3±3.7 Ma for the Cerro Farellon Complex granodiorite fits within the 95–70 Ma group of Suárez and de la Cruz (1997a), associated with extensional tectonics and bimodal volcanism. All three of these dates also correlate well with the Mid Cretaceous Rb-Sr isochron ages of 88±2–117±1 Ma reported for plutons in the eastern part of the North Patagonian Batholith contacting the Ibáñez Formation by Pankhurst et al. (1999), and with the Cretaceous 114–75 Ma event of Parada et al. (2001). The 148 Ma Jurassic age for the Lago Esmeralda granodiorite may be correlated with either the early onset of North Patagonian Batholith magmatism or associated with later stages of the Ibáñez Formation magmatism.

Sample Number	Age (Ma) ±error(2σ)	Mineral	Formation	Utm East / Lat.	Utm North / Long.
Ar-Ar ages (This study):					
L5β	143.5 ± 2.1	Biotite	Ibáñez Fm. Ignimbrite, Peninsula Levicán	281170	4859500
F9B	151.8 ± 6.2	Muscovite	Ibáñez Fm. Ignimbrite, Peninsula Ibáñez	288074	4868214
Ga11C	150.3 ± 1.8	Biotite	Ibáñez Fm. Rhyolite, Cerro Cabeza Blanca	288426	4871485
CD9B	138.1 ± 4.9	Biotite	Divisadero Fm. Ignimbrite, Coyhaique	267771	4946000
Bert-2	107.7 ± 12.2	Hornblende	Cretaceous granitoid, Lago Plomo/Bertrand	660670	4792090
Lago Esmeralda	148.3 ± 4.0	Hornblende	Jurassic granitoid, south of Cochrane.	228533	4750175
PI 62	101.2 ± 2.6	Hornblende	Granitoid Stock cutting Ibáñez Fm.	273300	4872725
CF 20	89.3 ± 3.7	Biotite	Granitoid Stock cutting Divisadero Fm.	272387	4878345
Additional K-Ar ages (This Study):					
Ga11C	155.0 ± 2.8	Biotite	Late Ibáñez Fm. Rhyolite.	288426	4871485
Lago Esmeralda	147.0 ± 3.4	Hornblende	Jurassic granitod, south of Cochrane.	228533	4750175
K-Ar ages: Suárez and de la Cruz (1997b)					
CC-331	144.0 ± 4	Biotite	Ibáñez Fm. Ignimbrite, Chile Chico	273921	4834974
CC-328	144.0 ± 3	Biotite	Ibáñez Fm. Ignimbrite, Chile Chico	272878	4835205
CC-330	145.0 ± 3	Biotite	Ibáñez Fm. Ignimbrite, Chile Chico	272209	4835307
CC-190	146.0 ± 4	Biotite	Ibáñez Fm. Ignimbrite, Chile Chico	285820	4836346
CC-93-D	149.0 ± 4	Biotite	Ibáñez Fm. Ignimbrite, Chile Chico	276298	4819194
CC-47-2	150.0 ± 4	Biotite	Ibáñez Fm. Ignimbrite, Peninsula Levicán	281100	4859450
K-Ar age: Charrier et al. (1978)					
C-30-73	136.0 ± 3.0	Whole rock	Ibáñez Rhyolitic tuff, Rio Chacabuco.		
U-PB SHRIMP ages: Pankhurst et al. (2000).					
Puerto Ibáñez	153.0 ± 1	Zircon	Ibáñez Rhyolite, Puerto Ibáñez.		
Sierra Colorada	154.1 ± 1.5	Zircon	El Quemado Fm. Ignimbrite		
Rio Pinturas	156.2 ± 1.8	Zircon	?Chon Aike Fm. Ignimbrite		
Est. La Unión	154.5 ± 1.4	Zircon	El Quemado Fm. Ignimbrite		
C. Morla Vicuña	171.8 ± 1.2	Zircon	Tobifera Fm. Ignimbrite		
K-Ar ages: Suárez et al. (1997)					
FT-17	159.0 ± 4	Biotite	El Quemado Fm. Ignimbrite, Rio Correntoso.	47° 13'60"	71° 34'87"
FT-18	144.0 ± 4.0	Biotite	El Quemado Fm. Ignimbrite, Sierra Colorada.	47° 21'87"	71° 37'87"
FT-19	150.0 ± 4.0	Biotite	El Quemado Fm. Ignimbrite, Sierra Colorada.	47° 22'02"	71° 37'95"
FT-26	142.0 ± 4.0	Biotite	El Quemado Fm. Ignimbrite, Garganta de Oro.	47° 25'15"	71° 58'43"
Rb-Sr Isochron ages: Pankhurst et al. (1993); Rapela and Pankhurst (1993); Halpern (1973).					
Pto Deseado (1)					
	170.0 ± 4.0		Chon Aike Fm., Puerto Deseado region		
Pto Deseado (11)					
	168.0 ± 2.0		Chon Aike Fm., Puerto Deseado region		
Sierra Colorada	136.0 ± 6.0		El Quemado Fm., Sierra Colorada region		
Arroyo Verde					
	183.0 ± 2.0		Marifil Complex, Arroyo Verde-Estancia Marifil		
Sierra Negra					
	181.0 ± 7.0		Marifil Complex, C. del Ingeniero/Sierra Negra		
Dique Ameghino	181.0 ± 4.0		Marifil Complex, Dique Ameghino region		
Pen. Camerones					
	178.0 ± 1.0		Marifil Complex, Peninsula Camerones		

Table 6.1: Table of Ar-Ar data compared with selected K-Ar, U-Pb SHRIMP, and Rb-Sr Isochron data from previous authors.

Chapter 7

Discussion and conclusions

7.1 Internal stratigraphic units of the Ibáñez Formation: Formation vs Group

In recent publications (Suárez and de la Cruz, 1997a,b; Suárez et al., 1997) a tendency to refer to the Ibáñez Formation as the 'Ibáñez Group' or 'Grupo Ibáñez' has arisen, in conflict with previous nomenclature, in which the term 'Ibáñez Formation' is most commonly used (for example, Baker et al. (1981); Gust et al. (1985); Skarmeta (1974); Suárez and de la Cruz (1993, 1994b)). In order to upgrade the Ibáñez Formation to the Ibáñez Group, it is necessary to demonstrate that an Ibáñez Group comprises throughout the major part of its outcrop two or more distinctly mappable member formations, after the definition of Salvador (1994). This is possible, for example, with the overlying Coyhaique Group, which can be subdivided into the constituent Toqui, Katterfeld and Apeleg Formations (Ramos, 1976; Suárez and de la Cruz, 1994b). However, the Ibáñez Formation is a composite formation comprised of bimodal basic and silicic volcanic facies whose rocks are complexly interdigitated with volcaniclastic sedimentary rocks and very occasionally, with shallow marine sedimentation.

Previous work has defined areas within the Ibáñez Formation in which distinct volcanic and sedimentary facies can be identified (Suárez and de la Cruz, 1993), and as part of this study distinct facies associations have been described within the Ibáñez Formation mapped in the Ibáñez quadrangle. (See Chapter 3). Within the Ibáñez Quadrangle, the Ibáñez Formation can be shown to contain several volcanic facies associations. Caldera proximal deposits such as the thick welded and ponded ignimbrites intercalated with lacustrine shales, debris flow deposits and fining upwards deltaic sequences occur in the Rio Ibáñez Valley and near El Maitenal. Thinner welded and unwelded ignimbrite and tuff outflow sheets intercalated with epiclastic tuffaceous sandstones and gravels typical of river channels, overbank deposits and sheetflow floods occur on the Ibáñez and Levicán peninsulas, whereas rhyolitic domes and lavas with their associated breccias and block and ash deposits occur at Puerto Rey, Peninsula Levicán, southwest Cerro Pirámide and Cerro Cabeza Blanca. Also, at El Maitén, Estero Lechoso and Arroyo Zanjón Feo there are associations of basaltic to basaltic andesitic lavas, breccias and tuffs, often locally unconformable on silicic Ibáñez Formation tuffs and rhyolites, which may be interpreted as either isolated monogenetic eruptions or the remnants of andesitic stratocones. However, within the Ibáñez Quadrangle, within each of these facies associations, whereas local corellation on the order of a few 100m to 1km is possible, the degree of minor faulting and deformation makes defining a coherent internal stratigraphy of individual formations derived from single volcanic centres within the Ibáñez Formation in the area mapped difficult if not impossible. The one coherent internal stratigraphic contention for the Ibáñez Formation mapped in the Ibáñez Quadrangle is that in three locations (El Maitén, Puerto Ibáñez/Estero Lechoso and Arroyo Zanjón Feo), silicic tuffs and lavas of the Ibáñez Formation proper have a weathered erosion surface or paleotopography onto which basaltic andesitic lavas have been erupted, in one case in the hill west of El Maitén forming a valley fill sequence into eroded and weathered silicic tuffs. This may represent a final event in Ibáñez Formation volcanism and sedimentation in parts of the area mapped, but this is not certain, as at Cerro Pirámide these andesitic rocks are in turn overlain by up to 500m of silicic tuffs, ignimbrites and rhyolites, and at Cerro Cabeza Blanca the dome that forms the bulk of the mountain erupted through and onto these andesitic rocks, and contains biotite dated at 150 $\pm$ 1.8 Ma, a typical Ibáñez age. There are indications that at Lago Norte, from the sketch stratigraphic section showing andesitic lavas overlying weathered silicic tuffs (See Chapter 6) that an andesitic eruptive event also occurred in the upper Ibáñez Formation, although the rocks at Lago Norte extend into the Berriasian, while those at the Ibáñez Quadrangle are most likely Tithonian.

Thus it is my opinion that for the moment, it is premature to refer to the 'Ibáñez Group,' as at the present level of stratigraphic detail and correlation has shown little evidence of a coherent internal stratigraphy that would allow division into regional Formations. It may be tentatively said that within the Ibáñez quadrangle there is evidence for an andesitic 'member' erupted as a late event after a period of erosion, but given the degree of faulting between the andesitic outcrops, and the occurence of further typical Ibáñez silicic rocks overlying two of the three andesitic outcrop areas, it is difficult to justify elevation of the andesitic rocks mapped to the level of a formation within an 'Ibáñez Group'. However, given that individual facies associations and fragments of volcanic complexes may be readily identified, it may be appropriate to adopt the terminology 'Ibáñez Complex' or to merge the Ibáñez Formation with the El Quemado Complex, (with which it is often regarded as equivalent).

7.2 Ibáñez Formation Magmatism: Differentiation of the Ibáñez and Divisadero Formations

In most regions of the Aysen Basin where both the Ibáñez and Divisadero Formations are exposed in close proximity, local stratigraphy is usually adequate to separate the two. In particular, the presence of part or all of the Coyhaique Group marine transgressive-regressive sequence allows definition between the two silicic volcanic formations. However, this is not always so in some areas of the basin, particularly towards the margins of the basin or near areas of paleotopographic highs within the basin where the Coyhaique Group may be thin, patchy or altogether absent. Part of the initial aim of this study was to determine if there were distinct geochemical signatures for each formation that would allow identification via analysis when stratigraphic markers such as the Coyhaique Group were absent or at least inconclusive. Some defining characteristics of the Ibáñez and Divisadero Formations are compared in Table 7.1.

Table 7.1: Defining characteristics of the Ibáñez and Divisadero Formations.

Ibáñez Formation	Divisadero Formation
Main facies associations:	
Within caldera or near caldera facies: The Ibáñez Formation to the west of the quadrangle shows a thick (>1500m, perhaps up to 2000m, but possibly tectonically thickened) near caldera calc-alkaline rhyolitic volcanic facies, with thick ponded tuffs and individual ignimbrites up to 130m thick. There are associated lava breccias and domes, along with further ignimbrites, tuffs, lithic tuffs and breccias. Intercalated with these rocks are sedimentary facies that include deltaic sandstones with some trace fossils and wood fragments, plus debris flows, turbidites and lacustrine shales. *Rhyolitic Domes and Proximal Ignimbrite Outflow sheets:* These rocks occur principally on the Peninsula Levicán and Peninsula Ibáñez. Dacitic or rhyolitic domes and coulee lava flows with associated breccias, surge tuffs and feeder dikes occur, and are erupted within, through or faulted against extensive tuff and columnar jointed thin (<50m) ignimbrite sheets intercalated with fining upwards alluvial gravels and sandstones of floodplain or lacustrine sources. *Basalt to Basaltic Andesite lavas and possible Stratocone remnants:* Calc-alkali olivine basalt and basaltic andesite aa lava flows at El Maitén, Puerto Ibáñez and Arroyo Zanjón Feo. At these locations, basaltic to basaltic andesitic lavas up to 250m thick overlie older, weathered Ibáñez domes, tuffs and epiclastic sediments of the near caldera facies andignimbrite outflow sheet facies.	*Delta front and floodplain facies:* At Cerro Manchón, the Divisadero Formation is in gradational contact with the underlying tidal to delta front sandstones of the Apeleg Formation, and begins with floodplain overbank deposits of fine muddy 'redbed' sandstones with common wood fragments, massive slump deposits and lenses of channel sandstone. Within the slump deposits are blocks of sandstone containing algal oncolites, indicating lacustrine environments are present. *Distal Ignimbrite outflow sheet and flood plain facies:* At Cerro Manchón and Cerro Divisadero, above the redbeds are thick sequences of tuffaceous coarse through to fine sandstone sequences, with repeated fining upwards trends in tabular and trough crossbedded channel sandstone sequences, along with muddy laminated and thinly bedded overbank sandstones. In the Ibáñez Quadrangle these sequences are occasionally interrupted by thin (1–15m) tuffs and ignimbrites, while at Lago Frio and the Cerro Divisadero section the channel and floodplain sandstone facies are regularly interrupted by thick rhyolitic tuffs from 5–50m thick throughout the sequence. *Proximal Ignimbrite outflow sheet and floodplain facies:* At Cerro Montreal, tuffaceous coarse to fine fining upwards sequences of channel sandstone with intercalated muddy overbank sandstone deposits, similar to those of Cerro Divisadero and Cerro Manchón. However, at this location the sequence is regularly interrupted by massive coarsely stratified lithic breccias and thick to very thick (15–50m) lithic rich massive tuffs, and in particular one 160m massive tuff, commonly with cobble and block size lithics, and some megablocks >10m. This sequence is interpreted as being a more proximal ignimbrite outflow sheet facies than those described from Cerro Divisadero and Cerro Manchón. Rhyolitic dome complexes and andesitic lavas have also beed described from the Divisadero Formation (de la Cruz et al., 1994).

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Table 7.1: Defining characteristics of the Ibáñez and Divisadero Formations *cont*

Structural Geology:	
The Ibáñez Formation within the Ibáñez Quadrangle is moderately deformed, mainly with moderate to intense minor normal and reverse faults, usually between a few hundred metres to 1–2km between faults, such that beds can generally be correlated for only a few hundred metres and seldom more than 2km. In areas such as the Peninsula Levicán or near El Maitén, where north-south and east-west faults cross, many blocks of Ibáñez Formation tuffs are tilted, with dips up to 40°. Folding is rare, present only in two locations, a rollover anticline at Puerto Ibáñez and an anticline at La Pedregasa associated with deformation by a dacitic intrusion. Most faults are normal faults, but often with a significant oblique component, as at Cerro Bandera Oeste, and deform only the Ibáñez Formation, with only three locations (Arroyo Zanjón Feo, Estancia Moroma and La Pedregasa) where faults can be seen to cut and deform the Ibáñez Formation, Coyhaique Group and Divisadero Formation. Therefore most deformation of the Ibáñez Formation is probably coeval or just after Ibáñez Formation activity, and previous to Coyhaique Group and Divisadero Formation sedimentation.	The Divisadero Formation within the Ibáñez Quadrangle is only slightly deformed in comparison to the Ibáñez Formation. At Cerro Farellón and Cerro Manchón the Divisadero Formation is near flat lying, with beds dipping ¡5° E, with little faulting or folding except where involved in the Cerro Farellón collapse structure, in which the cap of Divisadero Formation rocks subsiding into the microgranitoid have drag folds near the bounding faults and conjugate normal faults within the subsiding block. Major reverse faults cut and fold the Divisadero Formation at La Pedregasa and Estancia Moroma, causing folding and shearing in the Coyhaique group and Divisadero Formation. At Cerro Divisadero minor normal faulting trends NW and NE, while at Cerro Montreal there are NNE directed normal faults. Regular small scale block faulting like that found in the Ibáñez Formation is absent.
Petrography	
Ibáñez Formation tuffs: Rhyolitic tuffs with common crystal phases of quartz, sodic plagioclase, occasional biotite and sanidine. Lithic fragments are common, and often large. Propylitic type alteration with sericite, saussurite, k-feldspar, calcite and clay alteration of feldspar and vitric material is widespread, as is low grade metamorphism, occasionally up to albite epidote or hornblende facies. Most are vitric tuffs, but crystal and lithic proportions are high. Vitroclastic textures are present but generally destroyed by felsitic or mosaic recrystallisation textures. *Ibáñez Formation Rhyolites and Dacites:* Porphyritic flowbanded rocks with phenocryst phases of quartz, sodic plagioclase and biotite, with traces of k-feldspar in rhyolites and altered biotite or pyroxene in dacites. Groundmass textures in dacites are flowbanded pilotaxtic feldspar microphenocrysts with some recrystallised quartz-feldspar poikilomosaic textures. Groundmass textures in rhyolites are either felsitic or spherulitic undercooling textures, with some flowbanding ,and ubiquitous mosaic recrystallisation to quartz/k-feldspar. Propylitic alteration is common. *Ibáñez Formation Olivine Basalts and Basaltic Andesites:* Porphyritic or aphanitic rocks with phenocryst and microphenocryst phases of olivine-augite-labradorite-oligoclase-magnetite and augite-labradorite-oligoclase-magnetite respectively, with sparse interstitial k-spar and quartz, intergranular groundmass textures, sieve textured and swallowtailed plagioclase, skeletal olivine in the olivine basalts and pilotaxitic to intergranular groundmass textures. Alteration is common, with sericitisation and k-feldspar replacement of plagioclase and often albite-epidote facies contact metamorphism.	*Rhyolitic tuffs of the Divisadero Formation:*Divisadero Formation tuffs generally have low crystal contents, very low lithic contents, and high vitric ash and pumice content. Crystal phases are sparse quartz and sodic plagioclase with occasional biotite and rare k-feldspar. All plot as vitric tuffs, although lithic rich ignimbrites and lag breccias do occur at Cerro Montreal. Vitroclastic textures are very well preserved, and generally only partially devitrified with little development of mosaic recrystallisation textures, and some glass remains in welded tuffs at Cerro Divisadero, as do occasional spherulites. Widespread alteration of feldspars and mafic crystal fragments, devitrification, and recrystallisation to felsitic or mosaic textures is usual only when secondary thermal events have occurred, particularly around the microgranitic intrusions in the Ibáñez Quadrangle, where both Divisadero and Ibáñez Formation tuffs may reach albite-epidote and hornblende hornfels facies. *Divisadero Formation Basaltic Andesite:*The sole Divisadero Basaltic andesite from northeast of Estancia Moroma is a porphyritic rock with sieve textured labradorite - andesine and sparse augite phenocrysts in a groundmass of pilotaxitic andesine microphenocrysts with k-feldspar rims and intergranular augite, magnetite and traces of interstitial quartz.

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Table 7.1: Defining characteristics of the Ibáñez and Divisadero Formations *cont*

Geochemistry:	
The geochemistry of the Ibáñez Formation is strongly subduction related, with a bimodal suite of metaluminous calc-alkali basalts to basaltic andesites and metaluminous to peraluminous calc-alkaline dacites to rhyolites. A distinct major element compositional gap between the basic and silicic rocks suggests a mantle wedge source for the mafic rocks and perhaps a crustal source for the silicic rocks. Trace element signatures have LIL enrichment and HFS depletion, with Nb, Sr and Ti depletion spikes compatible with a subduction influenced source and fractionation of plagioclase and magnetite, or possibly with inheritance of the signature by re-melting of older material with a subduction derived signature.	The geochemistry of the Divisadero Formation is also subduction related, with a silicic suite of calc-alkaline metaluminous to peraluminous rhyolitic ignimbrites of very similar composition to the Ibáñez Formation silicic rocks. Lack of basic samples precludes identification of a compositional gap, but trace element composition shows the subduction related Nb depletion along with Sr and Ti depletion. Divisadero Formation silicic rocks show no significant major element or trace element differences to the Ibáñez Formation, suggesting a similar or related petrogenesis or source.

Calc-alkaline subduction related igneous rocks are the dominant form of magmatism present in the Ibáñez quadrangle throughout the Mesozoic. The Ibáñez and Divisadero Formations, together with the later granitoid intrusions and the bulk of the minor intrusive rocks, show very similar characteristics and may all be related to magma generation in a subduction setting.

The Ibáñez Formation is a bimodal calc-alkaline suite with mafic rocks comprising calc-alkali basalts to basaltic andesites, and silicic rocks represented by dacites, rhyo-dacites and rhyolites. Due to the effects of weathering and common hydrothermal alteration and contact metamorphism up to hornblende hornfels facies in some areas, major element geochemical trends are indistinct. However, major element chemistry of the Ibáñez Formation is similar if not indistinguishable from much of the other calc-alkaline Jurassic volcanism in Patagonia (see Fig. 5.1 with overlay data (Pankhurst et al., 1998))). The Ibáñez Formation also compares well with calc–alkaline rocks from Taupo Volcanic Zone, New Zealand in both major element and trace element distribution (See Figs. 5.1 and 5.5 through 5.8). In their major element trends, the basic and silicic rocks of the Ibáñez formation can be separated into two fields separated by a compositional gap. In MnO, K_2O, TiO_2 the trend and gradient of the two fields are linear and may be interpreted as a result of crystal fractionation, but in MgO, CaO, Al_2O_3, Fe_2O_3 and Na_2O the two fields exhibit slightly to greatly different gradients, and while basic and silicic rock trends are linear, the two fields often do not plot on the same trend. The trace element distribution of the Ibáñez Formation exhibits LIL enrichment and HFS depletion in all samples, and low Nb levels typical of magmatic arc rocks (Wilson, 1989). Silicic rocks from dacite to rhyolite show increasing depletion of Ba, Sr and Ti which can be attributed to fractionation of feldspars and magnetite respectively. The bimodal nature of the Ibáñez Formation may be interpreted as a suite of basic-intermediate rocks derived from mantle wedge melting above a subduction zone, with probable assimilation and fractionation during migration through the continental crust. The more voluminous silicic rocks could represent crustal melting driven by the excess heat from emplacement of the basic subduction magmas into the crust. Parada et al. (2001) present Sr-Nd isotopic data for basaltic to intermediate rocks from the Aysén region, which indicate that of the Mesozoic-Eocene back-arc extensional volcanic rocks in the Aysén region, those from the south of 46°30' are subalkaline with enriched Sr-Nd signatures indicating lithospheric affinity, while those to the north of that parallel are more alkaline and have more depleted Sr-Nd signatures similar to asthenospheric derivation. The felsic rocks of the southern magmatic domain of Parada et al. (2001) was also noted to have lower ϵNd values and lightly higher $^{87}Sr/^{86}Sr$ ratios than those to the north of 46°30', interpreted as evidence of a greater degree of crustal material in the magma sources. The isotopic data of Parada et al. (2001) may indicate that crustal thinning due to back-arc extension was more active to the north of the Aysén region, leading to less crustal melting and assimilation, than to the south, where greater crustal thickness would lend more crustal influence to volcanism. However, to evaluate the degree to which these possibilities may apply to the Ibáñez Formation, further radiogenic isotope analysis is required.

The Divisadero Formation as sampled is of a narrower compositional range, and has only minor basic representatives. However, in major and trace element chemistry it plots in almost identical patterns to the Ibáñez Formation in all respects excepting for less scatter due to alteration. It may also be interpreted as a suite of silicic magmas derived from crustal melts driven by basic underplating in a subduction zone. However, within this study few rocks that could well represent the basic-intermediate compositional suite for the Divisadero Formation were found, and so more work is required to further evaluate whether the Divisadero Formation contains the same bimodal compositional trends as seen in the Ibáñez Formation. It is evident from the major and trace element data (See Figs. 5.12, 5.13, and 5.14) that there is no significant difference in the geochemistry of the Ibáñez and Divisadero Formations, indicating that as a mapping tool for determining the two formations where stratigraphic data is inconclusive, simple major and trace element geochemistry is inconclusive. As discussed above, the silicic rocks that dominate both formations could be derived from crustal source regions of similar composition, with anatexis driven by underplating derived from a similar subduction influenced mantle wedge in both cases. Therefore it may be necessary to investigate any differences between the two formations with radiogenic isotope geochemistry that can pick out isotopic differences or similarities in the source regions. If, for instance, both sets of silicic rocks are derived from melted crustal rocks from approximately the same area, there may have been significant isotopic depletion of the Ibáñez source region. Therefore, the isotopic signature of that source region when remobilised by renewed Mid Cretaceous magmatism to generate the Divisadero Formation, may show evidence of depletion from the earlier Ibáñez melting event. Greater use of robust radiometric dating methods that are unlikely to be easily re-set by subsequent thermal events may also be useful.

7.3 The petrogenesis, deposition and deformation of the Ibáñez Formation in the upper Jurassic - earliest Cretaceous Austral basin

The volcanism and deposition of the Ibáñez Formation has been associated with either subduction related (Demant, 1995; Gust et al., 1983, 1985) or plume related (Pankhurst et al., 1998; Pankhurst and Rapela, 1995; Pankhurst et al., 2000) basic intrusions driving crustal anatexis leading to widespread silicic volcanism. More recent workers tend to emphasise the subduction related affinity of the Ibáñez Formation, although it may still be influenced by the heat and magma influx of the declining stages of the proposed mantle plume event that drove the major silicic volcanism of the older and more eastern silicic provinces of central Patagonia, (Pankhurst et al., 2000; Riley et al., 2001). In particular, Pankhurst et al. (2000); Riley et al. (2001) define three silicic magmatic events in the Jurassic of Patagonia, V1 (188–178Ma), V2 (172–162Ma) and V3 (157–153Ma), of which the earlier V1 event has a 'within-plate' geochemical signature and is related to plume and crustal thinning driven lower crustal anatexis (see also summary in Geological Setting, Chapter 1), whereas the later V2 and V3 events are of a more subduction related geochemical signature from the western Gondwana margin. Of these three events, the Ibáñez Formation occurs at the upper limit of V3, with a well defined subduction related major and trace element geochemistry typical of destructive plate margins, with a low Nb signature (see Fig. 5.9), and Ar-Ar ages falling between 143-150Ma, although fossil data from Lago Norte indicates a continuation of activity beyond the V3 event into Berriasian times (see Fig. 6.3). The younger ages of the Ibáñez Formation could be explained as a dominantly subduction based system of mantle wedge basic magmas underplating continental crust and driving crustal anatexis with the possibility of some input from the last stages of lateral migration of the expanding remnants of a plume head as it spread and thinned against the base of the continental crust, having a later effect on the Ibáñez region than the older silicic provinces further east which received the bulk of the plume input (Fig. 7.1, Tithonian-Berriasian).

The tectonic setting of the Aysén Basin into which the Ibáñez Formation and later rocks were deposited is generally accepted as an ensialic back arc basin (Bell et al., 1994; Townsend, 1995; Parada et al., 2001). Whereas the Aysén Basin was unable to initiate back-arc seafloor spreading (as occurred in the Rocas Verdes/Sarmiento Complex further south, at circa 150Ma (Mukasa and Dalziel, 1996)) by Ibáñez times the presence of intercalations of rippled sandstones and mudstones with plant fossils, *Ophiomorpha* and *Thalassinoides* ichnofacies in the tuffs of the Ibáñez area, and the Berriasian marine fau-

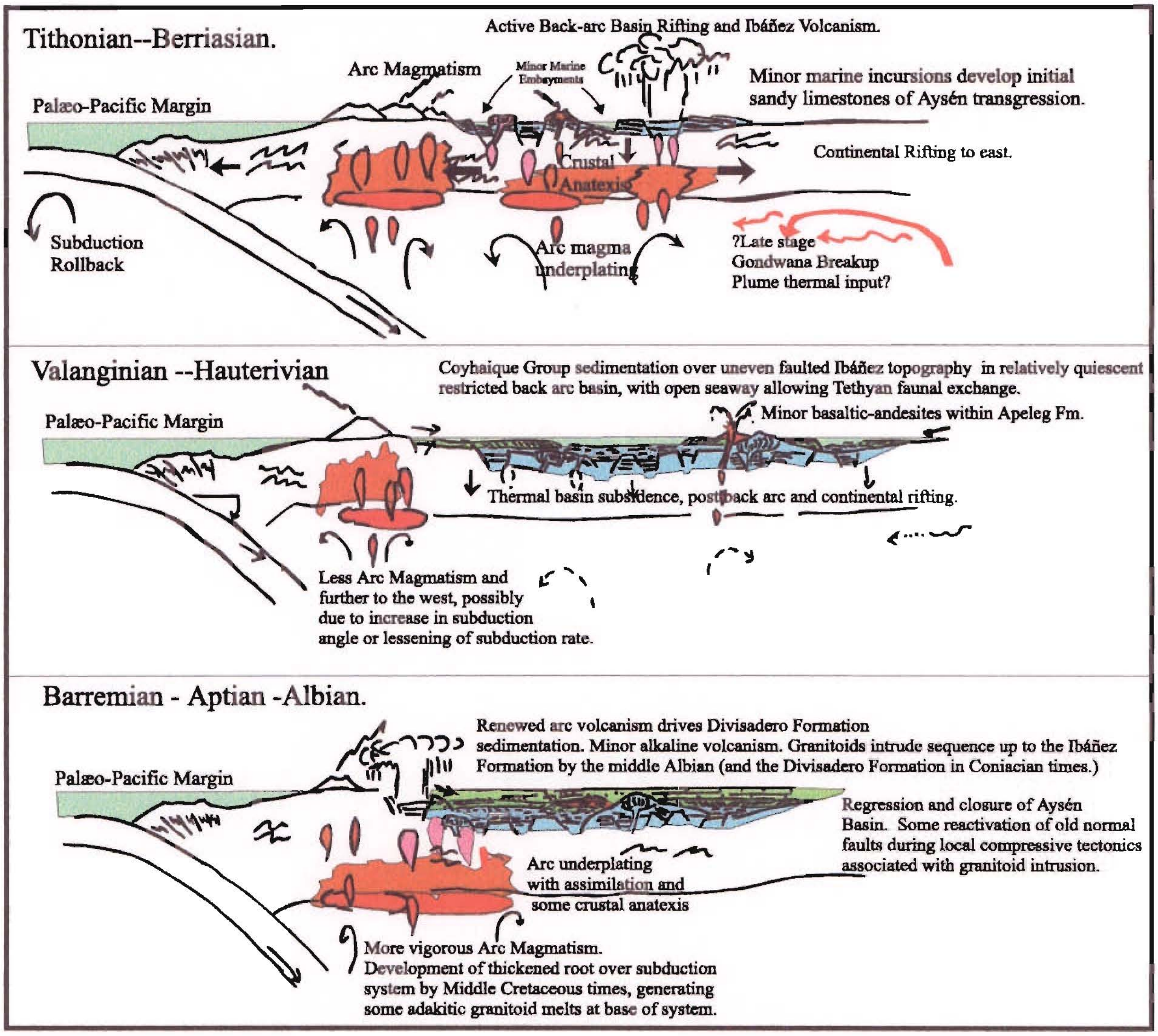

Figure 7.1: Plate tectonic cross sections for the Ibáñez Area from the Tithonian to Albian.

nas at Lago Norte, indicates sufficent subsidence to keep some sedimentation occurring in sub-aqueous environments at or near sea level. This subsidence allowed marine incursions into the Ibáñez Formation despite the accumulation of up to 1000m of silicic volcanic rocks. Diemer et al. (1997) note a similar occurrence of *Ophiomorpha* and *Thalassinoides* in conjunction with heterolithic rippled sandstones and imbricated pebble conglomerates as suggestive of brackish to marginal marine environments, in the upper parts of the early Cretaceous fore-arc basin fan delta deposits of the Puerto Barroso Formation on the Taitao Peninsula. In addition to the early marine incursions during Ibáñez times, after the Berriasian, the presence of Hauterivian faunas of Tethyan affinity in the Katterfeld Formation at Cerro Manchón (see Chapter 6 and Aguirre-Urreta et al. (2000)) indicates some degree of open seaway connections through the upper Hauterivian to Barremian - Aptian times, via either the Austral Basin or the Chubut Basin with a proto-Atlantic seaway and the western Tethyan realm (see Fig.1.7 and 7.1 Valanginian-Hauterivian). The Jurassic north-south oriented normal faulting deforming the Ibáñez Formation can be related to back-arc extension rather than latest Jurassic - earliest Cretaceous continental rifting, with the back-arc extension beginning to open the Aysén Basin in the Kimmeridgian - Tithonian. However, few of the normal faults mapped within the Ibáñez Formation cut later rocks, so basin subsidence from the later Berriasian up to Hauterivian and Aptian times may be ascribed to post rifting thermal subsidence as proposed by Gust et al. (1985); Suárez and de la Cruz (1996, 1997a). Back arc extension in the latest Jurassic may be driven via subduction roll-back at the Pacific margin, but the presence of the Tethyan faunas in the Katterfeld Formation by Hauterivian times suggests that the Pacific marginal north-south oriented Aysén back-arc basin may also have been influenced by a breakthrough of Gondwana rifting related basins, such as the Chubut Basin, from the east, or from an extension of back-arc rifting via the south from the Austral Basin. The calm, anoxic sedimentation conditions of the Katterfeld Formation, however, suggest a fairly enclosed marine embayment (Bell et al., 1994), so it is likely that the Aysén Basin was open via only one of these seaways, not both, or had only very narrow connections to either.

Whether subduction related or crustal anatexis related, the Ibáñez Formation volcanic event led to the development of extensive silicic volcanic eruptive centres, with related epiclastic sedimentary sequences, and to a lesser degree basaltic and basaltic andesitic eruptive centres. Within the Ibáñez Quadrangle, there is abundant evidence for these facies. Caldera or caldera proximal deposits are well exposed in the Rio Ibáñez, with thick sequences of ponded ignimbrites intercalated with fining upwards deltaic systems, lacustrine shales, small turbidite sequences and debris flows, all of which indicate sedimentation in the presence of standing water, which could be within caldera basins or or back-arc rift faulted basins. The presence of minor rhyolitic intrusions with peperitic characteristics could be interpreted as intrusions into wet sediments within a caldera sequence. However, an actual topographic or structural feature in the mapped area that may determine whether these rocks are part of an intra-caldera sequence is either not present or has been destroyed or masked by later faulting.

Rhyolitic domes and lavas are also common, and are intercalated with both the thick ignimbrite sequences in the Rio Ibáñez valley and with the more extensive thinner ignimbrite outflow sheets and tuffaceous sandstones of the Peninsula Ibáñez and Peninsula Levican. Associated with the domes are coeval lava breccias and occasional block and ashflow tuffs and/or basal surge tuffs.

Within the upper parts of the Ibáñez Formation, the erosion surfaces mapped west of El Maiten and at Arroyo Zanjon Feo, indicate active erosion between volcanic episodes, with infilling of this paleotopography by later olivine basalts and basaltic andesites. Silicic volcanism continued after the andesitic episode, as silicic tuffs and a rhyolite dome overly the basaltic andesites at Cerro Cabeza Blanca. These basaltic andesitic lavas may be either isolated events or the partial remnants of stratocone volcanism. Similar sequences have been described at Lago Norte by Covacevich et al. (1994), and elsewhere in the Ibáñez Formation by Niemeyer et al. (1984); de la Cruz et al. (1994).

7.4 The deposition of the Coyhaique group and its relationship to the overlying Divisadero Formation

The Coyhaique group is incomplete in the Ibáñez Quadrangle, as it lacks the basal limestones of the Toqui Formation (Suárez and de la Cruz, 1993). However, both the Katterfeld Formation blackshales and the Apeleg Formation sandstones are present. These blackshales represent low energy pelagic and anoxic sedimentation in a restricted basin (Townsend, 1995), with fault controlled thickness relationships related to possible half grabens (Hechem et al., 1993) developing during lower Cretaceous rifting and marine transgression in the backarc Aysén Basin portion of the Austral basin (Bell and Suárez, 1997). Whereas the overlying Apeleg Formation shows little major thickness variation, generally varying between 50-120m, the Katterfeld Formation shows dramatic changes in thickness, being about 250m thick east of Cerro Farellón, in excess of 500m at Cerro Manchón and south of Cerro Farellón, but present as trace amounts only at Estancia Moroma. These changes in thickness may be due in part to a significant degree of paleotopography on the underlying Ibáñez Formation unconformity surface on which the Katterfeld Formation is deposited, or possibly due to erosion of the Katterfeld Formation before Apeleg Formation deposition. However, if extensional tectonics that deformed the Ibáñez Formation by normal and oblique faulting in the late Jurassic and Early Cretaceous were still active during Katterfeld Formation sedimentation in the Hauterivian, these thickness variations may be due to a small half graben or similar fault bounded local basin development beneath the current Cerro Farellón - Cerro Manchón area. The reverse fault deforming the Ibáñez Formation, Coyhaique Group and Divisadero Formation east of La Pedregasa and in Rincon Los Arroyos could be a good candidate for a normal fault bounding a half graben basin that has been reactivated by post Divisadero Formation compressive tectonics. Certainly this fault trends towards Cerro Manchón, and would have formed the eastern margin of a half graben collecting thick blackshales in that area. Similar fault bounded deposition for the Katterfeld Formation has been suggested by Hechem et al. (1993), for exposures in the Lago Fontana region, in addition to thickness variations produced by static relief in the Ibáñez Formation. Further work may be necessary in the stream outcrops around Cerro Farellón to determine the nature of the contact of the Katterfeld Formation with the Ibáñez Formation, and perhaps to identify any facies within the Katterfeld Formation that may indicate deposition in a fault bounded basin.

The Apeleg Formation in the Ibáñez Quadrangle matches the marine and deltaic facies described by Bell et al. (1994); Gonzalez-Boronino and Suárez (1995); Bell and Suárez (1997). The exposures at Cerro Manchón are a lower member of prograded tidal trough and herringbone crossbedded sandstones and are in gradational contact with the upper Katterfeld Formation. The Apeleg Formation then fines upwards as a massive foreset crossbedded prodelta sequence, which in turn grades upwards into alluvial gravels and delta top/flood-plain deposits in gradational or paraconformable contact with the lower Divisadero Formation. Further east, at Estancia Moroma, the Apeleg Formation is of a more sub-littoral facies, with trough, channel and hummocky or swaley crossbedding and an onlap contact relationship with the Ibáñez Formation unconformity surface, without the presence of the Katterfeld Formation. Further Northeast at Cerro Cabeza Blanca and Arroyo Zonjon Feo, the Apeleg Formation itself is absent, and the Divisadero Formation rests unconformably on the Ibáñez Formation, thus illustrating the presence of significant paleotopography in the Ibáñez unconformity surface and the onlap relationship of the Coyhaique Group in the eastern portion of the Ibáñez Quadrangle. At Estancia Moroma, the Apeleg formation does not grade into the Divisadero Formation, but rather is intercalated in its upper parts with breccias and surge deposits of a small andesitic tuff deposit, although this exposure is not well mapped and needs further work (GR 4870800 286 000).

Hence in the Ibáñez Quadrangle, the Katterfeld Formation has served to fill in depressions in the Ibáñez Formation unconformity surface, whereas the prograding tidal and deltaic sandstones of the Apeleg Formation have covered over all but the highest Ibáñez Formation. In turn the last high sections of the Ibáñez Formation are unconformably overlain by Divisadero Formation rocks in occasional locations where the Coyhaique Group sediments were not deposited or have been eroded prior to Divisadero Formation sedimentation (see Fig. 7.1, Valanginian-Hauterivian).

7.5 The deposition of the Divisadero Formation

The Divisadero Formation within the Ibáñez Quadrangle is dominated by floodplain channel sandstones and overbank deposits, with occasional interruption by airfall tuffs and ignimbrites, and is probably no younger than Aptian in age. The Divisadero Formation is sometimes in gradational or paraconformable contact with the Apeleg Formation, whereas at Estancia Moroma it overlies basaltic to andesitic tuffs in the upper Apeleg Formation, and further east in Arroyo Zanjón Feo it is in unconformable contact with the Ibáñez Formation.

The largest Divisadero Formation tuffs and ignimbrites in the Cerro Manchón section are usually 20m or less, with only three thick tuffs present in the 500m measured section, whereas tuffs from the type section of the Divisadero Formation at Cerro Divisadero nine 50-60m thick tuffs are exposed, and at Cerro Montreal seven thick tuffs are present, from 5-160m. Thus it is evident that the Divisadero Formation in the Ibáñez Quadrangle is significantly more distal than that from the Coyhaique region; exposures at Cerro Montreal are the most proximal facies to an eruptive centre, judging from the to the large size of lithic blocks present in the ignimbrites.

Sedimentation in the Divisadero Formation is dominated by deltaic plain muddy sandstone overbank deposits at the base, with migrating channel deposits and occasional debris flows, above which the bulk of the formation is comprised of fining upwards sequences of tuffaceous channel sandstones and mudstones with airfall tuffs and occasional distal ignimbrites. The more proximal facies of the Divisadero Formation at Cerro Divisadero, other than having more regular disruption of the floodplain system by large tuffs and ignimbrites, is very similar to that exposed in the Ibáñez Quadrangle. As the exposures in the Ibáñez area are slightly older (lower Albian, Suárez and de la Cruz (1994b)) than those of the Cerro Divisadero area (upper Albian, Suárez and de la Cruz (1994b)) and have fewer thick tuffs, the greater frequency of large tuffs at Cerro Divisadero and Cerro Montreal may indicate an increase in silicic eruptive events in the upper Albian. Within the Ibáñez region, the Divisadero Formation has no well exposed eruptive centres, unlike the Coyhaique region where, as well as ignimbrite outflow sheet/floodplain facies, dacitic and rhyolitic domes, caldera fill, surtseyan basalt cones, and andesitic lavas have been described (de la Cruz et al., 1994).

7.6 Post Ibáñez and Divisadero volcanic events

After the deposition of the Ibáñez Formation, Coyhaique Group and Divisadero Formation, extensive plutonic and hypabyssal magmatism and some extrusive magmatism occurred. Defining exact timing for these intrusive rocks is difficult, as the Ibáñez Formation is host to a wide range of basaltic, andesitic, basaltic trachyandesitic, trachyandesitic, dacitic and rhyolitic hypabyssal intrusive rocks, some of which may be coeval with the Ibáñez Formation, whereas others may be related to the Divisadero Formation, or the Cerro Pirámide and Cerro Farellón granitoid complexes, or later events such as the eruption of the Cerro Pico Rojo peralkaline rhyolites or the Plateau Basalts. The bulk of these rocks, although often much altered with high LOIs, have subduction related volcanic arc geochemical signatures (see Chapter 5) but, without concise stratigraphic control or radiometric dating, may be freely attributed to episodes of subduction related magmatism from at least the early Cretaceous to the Miocene.

Leaving the many minor intrusive rocks aside, during the mid Cretaceous, after the deposition of the local Divisadero Formation, large granodiorite to tonalitic stocks, dikes and sills of the Puerto Ibáñez - Cerro Farellón - Cerro Pirámide complexes were intruded through the Ibáñez and the Divisadero Formations. This is most likely to have happened between the upper Albian and the Turonian, with the timing of magmatism suggested by Ar-Ar ages of 101.2±2.6 Ma from the La Masira stock and 89.3±3.7 Ma from the main portion of the Cerro Farellón complex. These rocks are metaluminous calc- alkaline diorites, granodiorites and tonalites, with quartz-plagioclase-hornblende-biotite dominated mineralogy and accessory phases of titanite, apatite, zircon, ilmenite and epidote, indicating an I-type source after the scheme of White and Chappell, (1977). They show generally subduction related trace element patterns, with HFS depletion and LIL enrichment. In most samples a Nb, Ti and slight Sr depletion spike pattern is present, although not as strongly developed as in the Ibáñez and Divisadero Formation host rocks. Similar major and trace element chemistry is present in the two samples analysed from the Patagonian Batholith at Lago Bertrand (Mid Cretaceous) and Lago Esmeralda (Jurassic), which indicates that the plutonic calc alkaline rocks from the Ibáñez Quadrangle are able to be interpreted as isolated outliers from the main group of calc-alkaline mesozoic grantoids comprising the batholith. Their major and trace element chemistry also compares well with subduction derived rocks from the modern Taupo Volcanic Zone, (see Chapter 5, granitoids and microgranitoids), and may be described in terms of subduction influenced remelting and differentiation of continental basaltic underplate deeper in the crust (Pankhurst, 1999). Some rocks from the Cerro Farellón complex (CF6A, CF6B, CF16, CF19C and CF24), as well as most samples from the Cerro Pirámide stock (GA15,CP52,CP61,CP62,PI89) (as well as several of the calc-alkaline andesitic to dacitic minor intrusive rocks: PI79A, L17 A and B, WI30 and F20) show a slight but distinct enrichment spike in Sr, as well as Y depletion in some samples, (Figs 5.32B and C; Fig. 5.25D), which may indicate that some of the calc alkaline granitic intrusives and minor intrusives of the Ibáñez Quadrangle are adakitic in nature. Rather than invoking slab melting to achieve this trace element signature, it is proposed that it is derived from melting in a deep (circa 50-60km) hot source areas with garnet active in the source region and a lack of stable plagioclase, after Defant and Kepezhinskas (2001); Muir et al. (1995). If generated in this way, the adakitic signature of the Cerro Pirámide and Cerro Farellón rocks can be taken as evidence of the development of a thickened, underplated arc root by the middle Cretaceous (Fig 7.1 Barremian - Albian).

The intrusion of the Cerro Farellón and Cerro Pirámide complexes has led to minor Pb/Zn/Cu sulphide mineralisation of the adjacent Ibáñez and Divisadero Formation host rocks, as well as the development of metamorphic aureoles of albite epidote and hornblende hornfels facies. At Cerro Farellón, the Divisadero Formation has collapsed by stoping and sag folds into the underlying granitoid and may be a suspect for a caldera structure, although further mapping is required to investigate this possibility East of Cerro Pirámide, the granodioritic cone sheet intrusion northeast of Laguna Huncal appears closely associated with northwest southeast oriented open synclinal folding of the Divisadero Formation and Coyhaique Group. The smaller hypabyssal dacitic and trachydacitic stocks between La Pedregasa and Estancia Moroma are also closely associated with local reverse micro faulting that deforms both the Ibáñez and Divisadero Formations, and may be related to periods of compressive tectonics reported as occurring in the mid to late Cretaceous or earlier (Suárez and de la Cruz, 1997a, 2000).

As well as the common subduction related volcanic arc rocks ubiquitous as intrusive bodies in the Ibáñez Quadrangle, there is a minor presence of within-plate volcanic rocks. As minor intrusives, these are represented by two alkaline mugearitic rocks cutting the Divisadero and Ibáñez formations at Estancia Moroma and Peninsula Ibáñez, and a phonolitic dike on the Peninsula Ibáñez. The mugearitic rocks are without the Nb depletion spike of the subduction related rocks but instead show relatively flat and more primitive trace element patterns with slight HFS depletion. The phonolite dike shows strong depletions in Ba, Sr and Ti together with enrichment in Zr, is an example of an evolved and fractionated member of the sequence (see Fig. 5.27). Eruptive equivalents of these rocks are found in the Plateau Basalt lavas and the peralkaline Cerro Pico Rojo rhyolites, both of which show similar within-plate type geochemical signatures. The rhyolites in particular have matching trace element patterns to the phonolite, showing that the alkaline rocks present in the Ibáñez Quadrangle have fractionated to produce both phonolites and alkali rhyolites. Taken together, this group of within plate rocks may be interpreted as examples of the within-plate plateau basalts and associated rocks reported throughout this region of Patagonia (Petford et al., 1996; Petford and Turner, 1996; Singer et al., 1998; Gorring and Kay, 2001) with variable ages from the Paleocene to the Pleistocene. These rocks, which also outcrop at Chile Chico south of the area studied, have been related to the presence of windows in the slab beneath Patagonia, and possibly to melting assisted by a mantle plume present beneath the slab in the Paleocene to Miocene (Petford et al., 1996). To generate these rocks, Gorring and Kay (2001) advance an initial process of decompression melting of Ocean Island Basalt-like sub-slab material, contaminated by adakitic slab melts while rising and with further contamination by arc-signature material while passing through the supra-slab mantle wedge/basal continental lithosphere, together with some crustal contamination, to erupt as the main plateau lava sequence circa 12Ma, whereas a secondary less voluminous post-plateau set of magmas around 7Ma are modelled as less contaminated asthenospheric partial melts as the slab window(s) widen. Of the rocks in the Ibáñez Quadrangle, the minor intrusives with adakitic signatures (see Fig. 5.25D) and Nb depletion show similar characteristics to the earlier arc and slab contaminated main plateau magmas of Gorring and Kay (2001), while the Plateau Basalts, mugearitic minor intrusive rocks, phonolitic dike and the peralkaline Cerro Pico Rojo Rhyolites show less contaminated within-plate signatures and can be tentatively identified as a differentiation sequence similar to the later 7Ma post plateau magmas of Gorring and Kay (2001).

7.7 Some conclusions on the geological evolution of the Puerto Ibáñez area

- With respect to nomenclature, following the convention of Salvador (1994) in the International Stratigraphic Code, the adoption of the term Ibáñez Group is premature, and until more conclusive evidence of a more uniform internal stratigraphy comprising two or more mappable member formations that would comprise an Ibáñez Group is developed, the older term Ibáñez Formation is still more appropriate, although the adoption of either the term Ibáñez Complex or unification with the El Quemado Complex may also serve.

- For distinguishing between the Ibáñez Formation and the Divisadero Formation, stratigraphic and petrographic evidence, particularly with regard to levels of propylitic alteration, contact metamorphism and structural complexity, are more conclusive than major and trace element geochemistry, which show little difference between each formation, with both showing volcanic arc subduction related major and trace element geochemistry. Further work is required to expand the database of geochemical data on both formations, together with isotopic analysis to detail any differences in their petrogenesis which are not immediately apparent to major and trace element chemistry.

- Ibáñez Formation volcanism and deposition in the Ibáñez Quadrangle is characteristic of rhyolitic caldera volcanism and ignimbrite outflow sheets, with extensive development of accompanying volcaniclastic sedimentary deposits, along with subordinate rhyolitic dome facies and some evidence of basaltic to basaltic andesite stratocone volcanism. Thick sequences were allowed to accumulate due to probably coeval back arc extensional tectonics (Gust et al., 1985; Suárez and de la Cruz, 1997a), and the major part of the volcanism is probably Kimmeridgian to Tithonian in age, matching the mainly subduction related V3 157-153Ma silicic event of Pankhurst et al. (2000); Riley et al. (2001), with some activity reaching into the Berriasian, based on fossil evidence (Covacevich et al., 1994) and Ar-Ar and K-Ar data. There is with a possibility of thermal alteration resetting some ages in the Tithonian to Berriasian. K-Ar data from Suárez and de la Cruz (1997b) and U-Pb SHRIMP data from Pankhurst et al. (2000) give similar Kimmeridgian to Tithonian ages from samples within the Ibáñez Quadrangle and nearby at Chile Chico. Ar-Ar dating methods appear to have given reliable ages during this work but excess Ar was a problem during analysis, so greater precision and less sensitivity to thermal resetting may be obtained in the future by use of Rb/Sr or U-Pb methods.

- Coyhaique Group sedimentation in the Ibáñez Quadrangle occurred from at least the Hauterivian to Barremian/Aptian, with the Katterfeld Formation filling in the bulk of the basin, although significant high areas of the Ibáñez Formation were probably not buried until the Albian. Fossil evidence from the Katterfeld Formation shows the existence of seaway connections allowing access to Tethyan faunas at least in the Hauterivian. Regression occurred with the onset of Apeleg Formation deposition, probably during the Barremian, and was completed with the deposition of the Divisadero Formation during Albian times, with renewed arc volcanism.

- Deformation of the Ibáñez Formation in the Ibáñez Quadrangle occurred during the upper Jurassic and perhaps into the earliest Cretaceous, possibly coeval or shortly after Ibáñez volcanism, as predominantly north-south directed extensional normal and oblique faulting. Significant differences in the thickness of the overlying Katterfeld Formation of the Coyhaique Group may be due to this episode of faulting creating fault bounded basins. Few faults cutting the Ibáñez Formation also cut the Coyhaique Group, indicating that active tectonism may have slowed or stopped during the deposition of the Coyhaique Group. Compressive deformation and folding of the Ibáñez Formation in this area is rare, and when present appears to be mainly related to post Jurassic and generally post mid Cretaceous events related to the emplacement of the Cerro Farellón and Cerro Pirámide granitoids during the closing stages of, or after Divisadero Formation sedimentation. Some older faults cutting the Ibáñez formation may have been reactivated during later compressive deformation(s)

- Divisadero Formation rocks in the Ibáñez Quadrangle are dominated by epiclastic sedimentary processes, with intercalated distal rhyolitic volcanic deposits, in contrast to the Divisadero Formation at Coyhaique, which shows more proximal facies closer to the eruptive centres. The Ibáñez Quadrangle exposures of the Divisadero Formation may be slightly older than those at Coyhaique and may reflect a time of less active volcanism, although this may be an artefact of their distal deposition setting.

- Minor within plate basalts, basaltic trachyandesites, mugearites, phonolites and peralkaline rhyolites present in the Ibáñez quadrangle can be correlated to subducting slab window volcanism from the Paleocene to the Miocene as described by Petford et al. (1996); Gorring and Kay (2001).

Work on the rocks of the Ibáñez Quadrangle described in this study is incomplete, and directions for further work include:

- More detailed mapping of the structure of the Cerro Farellón granitoid complex with a view to determining the whether it is a caldera structure and if so, the type of collapse mechanism involved.
- Use of isotope geochemistry to determine what if any geochemical markers may exist to differentiate Ibáñez and Divisadero Formation rocks.
- Further examination of the many of the intrusive rocks found within the Ibáñez formation so as to determine their age relationships and which volcanic events they may be related to.

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References

Adams, C., 1999. Letter and table of Ar-Ar analysis results.

Aguirre-Urreta, M B, Suárez, M, Bruce, Z, de la Cruz, R, and Ramos, VA, 2000. Bioestratigrafia y Amonoideos de la Formación Katterfeld, (Cretacico Inferior) en Puerto Ibáñez, XI región, Chile. In *Congreso Geológico de Chile, 9°, Puerto Varas*, pages 183–187. SERNAGEOMIN.

Aguirre-Urreta, Maria B, 1998 a. Ammonites, e-mail 6 may 1998.

Aguirre-Urreta, Maria B, 1998 b. Ammonites, e-mail 16 december 1998.

Aguirre-Urreta, Maria Beatriz, 1999. Hemihoplitid ammonoids from the austral basin of Patagonia, Argentina. In Histon and Kathleen, editors, *Cephalopods; present and past; abstracts volume.*, volume 46 of *Berichte der Geologischen Bundesanstalt*, page 12. Geologische Bundesanstalt, Vienna, Austria. 5th international symposium on Cephalopods; present and past. Vienna, Austria. Sept. 6-9, 1999. Abstract; Serial; Conference-Document.

Baker, P E, Rea, W J, Skarmeta, J, Caminos, R, and Rex, D C, 1981. *Igneous history of the Andean Cordillera and Patagonian Plateau around latitude 46°S*, volume 303 of *Philosophical Transactions of the Royal Society of London, Series A: Mathematical and Physical Sciences*. Royal Society of London, London, United Kingdom.

Bates, C. C., 1953. Rational theory of delta formation. *American Association of Petroleum Geologists Bulletin*, 37:2119–2161.

Bell, C. M. and Suárez, M., 1997. The Lower Cretaceous Apeleg Formation of the Aysén Basin, Southern Chile. Tidal sandbar deposits of an epicontinental sea. *Revista Geológica De Chile*, 24(2):203–225. English Article DEC REV GEOL CHILE.

Bell, C M, Townsend, M J, Suárez, Manuel, and de, la Cruz Rita, 1994. The depositional environments of the Lower Cretaceous Coyhaique Group, Aysén Basin, southern Chile (45° - 46° S). In Campos, Eduardo ; Cecione, and Adriano, editors, *7 Congreso Geológico Chileno; actas*, volume 1 of *Actas - Congreso Geológico Chileno. 7, Vol*, pages 402–403. Universidad del Norte Chile, Departamento de Geociencias, Facultad de Ciencias, Antofagasta, Chile. 7 Congreso Geológico Chileno. Concepcion, Chile. Oct. 17-21, 1994. LAT: S460000; S450000; LONG: W0720000; W0743000.

Boggs, S., 1987. *Principles of Sedimentology and Stratigraphy*. Macmillan, New York.

Bonnichsen, Bill and Kauffman, Daniel F, 1987. Physical features of rhyolite lava flows in the Snake River plain volcanic province, southwestern Idaho. In Fink and Jonathan, editors, *The emplacement of silicic domes and lava flows.*, volume 212 of *Special Paper - Geological Society of America*, pages 119–145. Geological Society of America (GSA), Boulder, CO, United States. The emplacement of silicic domes and lava flows; The

Geological Society of America, annual meeting. Reno, NV, United States. 1984. Serial; Conference-Document.

Bowes, W., Knowles, P., Moraga, A., and Serrano, M., 1962. Reconnaissance for Uranium in the Aysén Area, Province. of Aysén. Technical report, U.S. Atomic Energy Comission, Washington, and Instituto de Investigaciones Geológicas, Chile.

Bradshaw, 1998. Conversation, confirming lack of microfossils in Punta de Marmoles samples.

Bruhn, R.L., Stern, C.R., and Dewit, M.J., 1978. Field and geochemical data bearing on the development of a Mesozoic volcano-tectonic rift zone and back arc basin in southernmost South America. *Earth and Planetary Science Letters*, 41:32–46.

Burt, R, 1999. Taupo Volcanic Zone Geochemistry data as Ms excel file.

Caldenius, C., 1932. Las Glaciaciones cuaternarias en la Patagonia y Tierra del Fuego. *Geografiska Annaler*, 14:1–64.

Carríc, Jacob, 1997. Lecture on Mineralisation at the Toqui Deposit by Mine Geologist at the Toqui Mine, Jacob Carríc, during IUGS 1997 fieldtrip, 14th January 1997.

Cas, R A F and Wright, J V, 1993. *Volcanic Successions, Modern and Ancient*. Chapman and Hall, 1993 reprint, 1st edition.

Charrier, R. and Covacevich, V, 1980. Paleogeografia y bioestratigrafia del Jurasico Superior y Neocomiano en al sector austral de los Andes Meridionales Chilenos. (42 ° - 56 ° Lat S.). In *II Congreso Argentino de Paleontologia y Bioestratigrafia y I Congreso Latinoamericano de Paleontologia, Actas.*, volume 5, pages 153–175. Buenos Aires.

Charrier, R, Linares, E, Niemeyer, H, and Skarmeta, J, 1978. Edades potasio-argon de Vulcanitas Mesozoicas y Cenozoicas del sector Chileno de la Meseta Buenos Aires, Aysén, Chile, y su significado Geológico. In *VII Congreso Geológico Argentino.*, volume II, pages 23–41. SO: Actas del Congreso Geológico Argentino. 7, Tomo II, Pages 23-41. 1979. Asociación Geológica Argentina. Buenos Aires, Argentina. 1979. Septimo Congreso Geológico Argentino. Neuquen, Argentina. April 9-15, 1978. LAT: S480000; S450000; LONG: W0710000; W0733000.

Covacevich, Vladimir, de, la Cruz Rita, and Suárez, Manuel, 1994. Primer hallazgo de fauna del Berriasiano Inferior (Neocomiano) en la Formacion Ibáñez, Region XI, Aysén. In Campos, Eduardo ; Cecione, and Adriano, editors, *7 Congreso Geológico Chileno; actas*, volume 1 of *Actas - Congreso Geológico Chileno. 7, Vol*, pages 425–429. Universidad del Norte Chile, Departamento de Geociencias, Facultad de Ciencias, Antofagasta, Chile. 7 Congreso Geológico Chileno. Concepcion, Chile. Oct. 17-21, 1994. LAT: S454500; S450000; LONG: W0710000; W0721500.

de la Cruz, Rita, Suárez, Manuel, and Demant, Alain, 1994. Facies volcanicas del Mesozoico de Aysén (sector noreste), 44°-47°Lat. S., Chile (formaciones Ibáñez y Divisadero). In Campos, Eduardo ; Cecione, and Adriano, editors, *7 Congreso Geológico Chileno;*

actas, volume 1 of *Actas - Congreso Geológico Chileno. 7, Vol*, pages 27–31. Universidad del Norte Chile, Departamento de Geociencias, Facultad de Ciencias, Antofagasta, Chile. 7 Congreso Geológico Chileno. Concepcion, Chile. Oct. 17-21, 1994. LAT: S460000; S450000; LONG: W0713000; W0721500.

Deer, W. A., Howie, R. A., and Zussman, J., 1992. *An Introduction to the Rock Forming Minerals*. Longman Scientific & Technical, London, 2nd edition.

Defant, M J and Kepezhinskas, P, 2001. Evidence suggests Slab Melting in Arc Magmas. *EOS, Transactions*, 82(6):65, 68–69.

Demant, A., 1995. Volcanic Stratigraphy of the Northern Patagonian Andes, Coyhaique Region (44° - 46° S), Chile. In *Abstracts, Andean Geosciences Workshop*. Kingston University.

Demant, A., Belmar, M., Herve, F., Pankhurst, R., and Suárez, M., 1998. Petrology and geochemistry of the Murta basalts: a subglacial eruption in the Patagonian Andes (46° lat. S.), Chile. Relationship with the subduction of the Chile Ridge. *Comptes Rendus De L Academie Des Sciences Serie Ii Fascicule a- Sciences De La Terre Et Des Planetes*, 327(12):795–801. English Article DEC C R ACAD SCI SER II A.

Diemer, J A, Forsythe, R D, Englehardt, D, and Porter, C, 1997. An Early Cretaceous forearc basin in the Golfo de Penas region, southern Chile. *Journal of the Geological Society, London*, 154:925–928.

Elliot, T., 1978. Deltas. In H. G. Reading, editor, *Sedimentary Environments and Facies*. Blackwell, Oxford.

Espinosa, W. and Stambuk, V., 1971. Informe geológico preliminar sobre parte del territorio entre los paralelos 46° y 47° Lat. Sur, provincia de Aysén. *Instituto de Investigaciones Geológicas*.

Ferreti, A, 1961. *Geológía económica de la zona del Lago General Carrera*. Memoria de prueba, Universidad de Chile.

Feruglio, E., 1938. Nomenclatura estratigrafica de la Patagonia y Tierra del Fuego. *Boletin de Informaciones Petroliferas*, 15(171):82–95.

Feruglio, E., 1944. Estudios Geológícos y Glaciologicos en la region Lago Argentino (Patagonia). *Boletin Academia Nacional de Ciencias, Cordoba*, 37(1):3–255.

Folk, R L, Andrews, PB, and Lewis, D W, 1970. Detrital sedimentary rock classification and nomenclature for use in New Zealand. *New Zealand Journal of Geology and Geophysics*, 13:937–68.

Gilbert, G. K., 1885. The topographic features of lake shores. *U.S Geological Survey Annual Report*, 5:69–123.

Gonzalez-Boronino, G and Suárez, M, 1995. Paleoambientes sedimentarios de la Formacion Apeleg, Cretacico Inferior de la Cuenca de Aysén, Region XI, Chile. *Revista Geológica de Chile*, 22(1):115–126.

Gorring, M L and Kay, S M., 2001. Mantle Processes and Sources of Neogene Slab Window Magmas from Southern Patagonia, Argentina. *Journal of Petrology*, 42(6):1067–1094.

Gust, D A, Biddle, K T, Phelps, D W, and Uliana, M A, 1983. The tectonic setting of Middle Jurassic volcanism in southern South America. In *AGU 1983 fall meeting.*, volume 64 of *Eos, Transactions, American Geophysical Union*, page 893. American Geophysical Union, Washington, DC, United States. AGU 1983 fall meeting. San Francisco, CA, United States. Dec. 5-9, 1983.

Gust, D. A., Biddle, K.T., Phelps, D.W., and Uliana, M.A. ., 1985. Associated Middle to Late Jurassic volcanism and extension in southern South America. *Tectonophysics*, 116:223–253.

Halpern, Martin, 1973. Regional Geochronology of Chile South of 50° Latitude. *Geological Society of America Bulletin*, 84(7):2407–2422. Geological Society of America (GSA). Boulder, CO, United States. 1973. Serial.

Hechem, J J, Figari, E G, and F, Homovc J, 1993. Secuencias deposicionales en al Neocomiano del Lago Fontana, Chubut, Argentina. *Congreso Geológico Argentino Actas 12*, 2:119–123.

Heim, A, 1940. Geological observations in the Patagonian Cordillera (Preliminary report). *Eclogae Geologicae Helvetiae.*, 33(1):25–51.

Irvine, T N and Barragar, W R A, 1971. A guide to the chemical classification of common rocks. *Canadian Journal of Earth Sciences*, 8(523 -48).

Katz, H., 1962. Nuevos antecedentes sobre la geológia de Aysén. *Revista Minerales*, 78:20–33.

Lahsen, A, 1967. Geológia de la region continental de Aysén. *Instituto de Investigación Recursos Naturales, CORFO*, (Inf. 20):1–25.

Le Maitre, R.W., 1989. *A Classification of Igneous Rocks and Glossary of Terms.* Blackwell, Oxford.

Leanza, A., 1967. Anotaciones sobre los fosiles jurasico-cretacicos de Patagonia Austral (Coleccion Feruglio) conservados en la Universidad de Bologna. *Acta Geológica. Lilloana*, 9:121–187.

Lewis, D W, 1984. *Practical sedimentology.* Hutchinson Ross Publ. Co., Stroudsburg, PA, United States. An Apteryx book Book Distributed worldwide by Van Nostrand Reinhold Co., New York, NY, USA.

Maniar, Papu D and Piccoli, Philip M, 1989. Tectonic discrimination of granitoids. *Geological Society of America Bulletin*, 101(5):635–643. Geological Society of America (GSA). Boulder, CO, United States. 1989.

McDonough, W F, Sun, S S, Ringwood, A E, Jagoutz, E, and Hofmann, A W, 1992. Potassium, rubidium, and cesium in the Earth and Moon and the evolution of the mantle of the Earth. In M McLennan, Scott and Roberta Rudnick, editors, *The Taylor*

Colloquium; Origin and evolution of planetary crusts., volume 56 of *Geochimica et Cosmochimica Acta*, pages 1001–1012. Pergamon, Oxford, International. The Taylor Colloquium; Origin and evolution of planetary crusts. Canberra, Australia. Oct. 1-2, 1990. Serial; Conference-Document.

Mercer, J. H., 1976. Glacial History of Southernmost South America. *Quaternary Research*, 6:125–166.

Morner, N. A. and Sylwan, C., 1989. Magnetostratigraphy of the Patagonian Moraine Sequence at Lago Buenos Aires. *Journal of South American Earth Sciences.*, 2:385–390.

Mpodozis, C. and Ramos, V., 1989. The Andes of Chile and Argentina. In G. E. Ericksen, M. T. Caas Pinochet, and J. A. Reinemund, editors, *Geology of the Andes and its relation to hydrocarbon and mineral resources.*, volume 11, pages 59–89. Circum Pacific Council for Energy and Mineral Resources Earth Science Series., Houston.

Muir, R J, Weaver, S D, Bradshaw, J D, Eby, G N, and Evans, J A, 1995. The Cretaceous Separation Point Batholith, New Zealand: Granitoid Magmas formed by melting of mafic lithosphere. *Journal of the Geological Society of London*, 152:689–701.

Mukasa, S B and Dalziel, I W D, 1996. Southernmost Andes and South Georgia Island, North Scotia Ridge: Zircon U-Pb and muscovite ^{40}Ar/^{39}Ar age constraints on tectonic evolution of Southwestern Gondwanaland. *Journal of South American Earth Sciences*, 9(5/6):349–365.

Murdie, R. E., Styles, P, Prior, D. J., and Daniel, A. J., 2000. A new gravity map of Southern Chile and its preliminary interpretation. *Revista Geológica de Chile*, 27(1):49–63.

Niemeyer, H, 1975. *Geolgia de la regin entre el Lago General Carrera y el Rio Chacabuco, Provincia de Aysén, Chile.*. Memoria de prueba, Universidad de Chile.

Niemeyer, R Hans, Skarmeta, M Jorge, Fuenzalida, P Ricardo, and Espinosa, N Walter, 1984. Hojas Peninsula de Taitao y Puerto Aysén, region de Aysén del General Carlos Ibáñez del Campo. LAT: S470000; S450000; LONG: W0701500; W0743000. 1:500,000.

Norrish, K and Hutton, J T, 1969. An accurate x-ray spectrographic method for the analysis of a wide range of geological samples. *Geochimica et Cosmochimica Acta*, 33(4):431–453. Pergamon. Oxford, International. 1969. Serial.

Pankhurst, R J, 1999. Email confirmation of Ibáñez U-pb date, Mon, 26 Jul 1999.

Pankhurst, R J, Leat, P T, Sruoga, P, Rapela, C W, Marquez, M, Storey, B C, and Riley, T R, 1998. The Chon Aike province of Patagonia and related rocks in West Antarctica; a silicic large igneous province. *Journal of Volcanology and Geothermal Research*, 81(1-2):113–136. Elsevier. Amsterdam, Netherlands. 1998.

Pankhurst, R J, Riley, T R, Fanning, C M, and Kelley, S P, 2000. Episodic silicic volcanism in Patagonia and the Antarctic Peninsula; chronology of magmatism associated with the break-up of Gondwana. *Journal of Petrology*, 41(5):605–625. Oxford University Press. Oxford, United Kingdom. 2000. Serial.

Pankhurst, R J, Sruoga, P, and Rapela, C W, 1993. Estudio Geocronologico Rb-Sr de los Complejos Chon-Aike Y El Quemado a los 47° 30' L S. In *XII Congreso Geológico Argentino y II Congreso de Exploracion de Hidrocarburos*, volume IV, pages 171–178. Mendoza, Argentina.

Pankhurst, R.J. and Rapela, C.R., 1995. Production of Jurassic rhyolite by anatexis of the lower crust of Patagonia. *Earth and Planetary Science Letters*, 134:23–36.

Pankhurst, Robert J, Weaver, S D, Herve, F, and Larrondo, P, 1999. Mesozoic-Cenozoic evolution of the North Patagonian Batholith in Aysén, southern Chile. *Journal of the Geological Society of London*, 156(Part 4):673–694. Geological Society of London. London, United Kingdom. 1999. Serial.

Parada, M. A, Lahsen, A., and Palacios, C., 2001. Ages and Geochemistry of Mesozoic Eocene back-arc volcanic rocks in the Aysén region of the Patagonian Andes, Chile. *Revista Geológíca de Chile*, 28:25–46.

Pearce, J. A. and Cann, J. R., 1973. Tectonic setting of basic volcanic rocks determined using trace element analyses. *Earth and Planetary Science Letters*, 19:290–300.

Pearce, J. A., Harris, N. B. W., and Tindle, A.G., 1984. Trace element discrimination diagrams for the tectonic interpretation of granitic rocks. *Journal of Petrology*, 25:956–983.

Pearce, J. A. and Norry, M. J., 1979. Petrogenetic implications of Ti, Zr, Y, Nb variations in volcanic rocks. *Contributions to Mineralogy and Petrology.*, 69:33–47.

Petford, N, Cheadle, M, and Barreiro, B, 1996. Age and Origin of Southern Patagonian Flood Basalts, Chile Chico Region (46°45'S). In *Third ISAG, St Malo, France*, pages 629–632.

Petford, N and Turner, P, 1996. Reconnaisance 40Ar/ 39Ar, age and paleomagnetic study of igneous rocks around Coyhaique, S. Chile. In *Third ISAG, St Malo, France*, pages 625–628.

Rabassa, J. and Clapperton, C. M., 1990. Quaternary Glaciations of the Southern Andes. *Quaternary Science Reviews*, 9:153–174.

Ramos, V. A., 1976. Estratigrafia de los Lagos La Plata y Fontana, Provincia del Chubut, Republica Argentina. In *Primer Congreso Geológico Chileno*, volume 1, pages A43–A64. Santiago.

Ramos, V. A., 1981. Descripcion Geológica de la Hoja 47ab. "Lago Fontana," Provincia del Chubut.

Ramos, V. A, Jordan, T. E, Allmendinger, R. W, Mpodozis, C, Kay, S. M, Cortés, J. M, and Palma, M., 1986. Paleozoic Terranes of the central Argentine-Chilean Andes. *Tectonics*, 5(6):855–880.

Rapela, C W and Pankhurst, R J, 1993. El Volcanismo Riolitico del noreste de la Patagonia: Un evento Meso-Jurasico de corta duracion y origen profundo. In *XII Congreso Geológico Argentino y II Congreso de Exploracion de Hidrocarburos*, volume IV, pages 179–188. Mendoza, Argentina.

Riccardi, A.C., 1988. *The Cretaceous System of Southern South America*. Memoir 168 / Geological Society of America.

Riding, R., 1990. Calcified Cyanobacteria. In R. Riding, editor, *Calcareous Algae and Stromatolites*, page 571. Springer-Verlag, Berlin.

Riley, T R, Pankhurst, R J, Leat, P T, Storey, B C, and Fanning, C M, 1998. Time relationships of pre-break-up Gondwana magmatism. In Almond, J ; Anderson, J ; Booth, P ; Chinsamy, Turan, A ; Cole, D ; De, Wit, J ; Rubridge, B ; Smith, R ; van, Bever, Donker, and J ; Storey, editors, *Gondwana 10; event stratigraphy of Gondwana.*, volume 27 of *Journal of African Earth Sciences*, page 160. Pergamon, London-New York, International. Gondwana 10; event stratigraphy of Gondwana. Cape Town, South Africa. June 28-July 5, 1998.

Riley, Teal R, Leat, Philip T, Pankhurst, Robert J, and Harris, Chris, 2001. Origins of large volume rhyolitic volcanism in the Antarctic Peninsula and Patagonia by crustal melting. *Journal of Petrology*, 42(6):1043–1065. Oxford University Press. Oxford, United Kingdom. 2001. Serial LAT: S654000; S654000; LONG: W0620000; W0624500.

Rollinson, H R., 1993. *Using Geochemical Data: evaluation, presentation, interpretation*. Longman Group.

Ruiz, C., 1945. Posibilidades mineras de Aysén. *Revista Chilenia de Historia y Geografia*, 97,98 & 99:131–66; 154–176; 404–414.

Salvador, A., editor, 1994. *I.U.G.S. International Stratigraphic Guide: a guide to stratigraphic classification, terminology and procedure.*. Geological Society of America, Geological Society of America, Inc., 3300 Penrose Place, PO Box 9140, Boulder, Colorado 80301, 2nd edition.

Singer, B. S., Ackert, R. P., Kurz, M. D., Guillou, H., and Ton-That, T., 1998. Chronology of Pleistocene glaciations in Patagonia; a 3 He, 40Ar/ 39Ar, & K-Ar study of lavas and moraines at Lago Buenos Aires, 46° S, Argentina. In *Geological Society of America, 1998 annual meeting*, volume 30 of *Abstracts with Programs - Geological Society of America*, page 30. Geological Society of America (GSA). Boulder, CO, United States. 1998.

Skarmeta, J, 1974. *Geologia de la region continental de Aysén entre los 45° y 46° Lat. Sur, Chile.*. Memoria de prueba, Chile.

Skarmeta, J, 1976a. Evolucion tectonica y paleogeografica de los Andes Patagonicos de Aysén (Chile) durante el Neocomiano. *Congreso Geológico Chileno*, I:B1–B15.

Skarmeta, J., 1978. Geologia de la Region Continental de Aysén entre el Lago General Carrera y la Cordillera Castillo, Carta Geológica de Chile No 29. Escala 1:250,000. pp 53.

Streckheisen, A., 1979. Classification and nomenclature of volcanic rocks, lamprophyres, carbonatites, and melilitic rocks: recommendations and suggestions of the IUGS subcommission on the systematics of igneous rocks. *Geology*, 7:331–5.

Suárez, M and de la Cruz, R., 1993. Mesozoic Stratigraphy and Palaeogeography of northern Patagonian Cordillera, (Lat 45°- 47° S), Chile. In *Second ISAG*, Abstracts, Second ISAG., pages 21–23. Oxford UK.

Suárez, M. and de la Cruz, R., 1994a. Estratigrafía del Jurássico-Cretácico Inferior, de la Cordillera Patagónica Oriental (45°- 46° Lat S), Chile, Facies y Paleogeografía. Technical report, Gobierno Regional XI Región - SERNAGEOMIN.

Suárez, M. and de la Cruz, R., 1994b. Estratigrafia y paleogeografia mesozoica de Aysén nororiental (45°-46° Lat. S),Chile. In Campos, Eduardo ; Cecione, and Adriano, editors, *7 Congreso Geológico Chileno; Actas*, volume 1 of *Actas - Congreso Geológico Chileno. 7, Vol*, pages 538–542. Universidad del Norte Chile, Departamento de Geociencias, Facultad de Ciencias, Antofagasta, Chile. 7 Congreso Geológico Chileno. Concepcion, Chile. Oct. 17-21, 1994. LAT: S455000; S451500; LONG: W0715000; W0721500.

Suárez, M and de la Cruz, R, 1997a. Cronologica Magmatica de Aysén Sur, Chile, (45°-48°30' S). In *VIII Congreso Geológico Chileno*, volume II, pages 1543–1547. Universidad Catolica del Norte.

Suárez, M and de la Cruz, R, 1997b. Edades K-Ar del Grupo Ibáñez en la parte oriental del Lago General Carrera (46°-47° S) Aysén, Chile. In *VIII Congreso Geológico Chileno*, volume 2, pages 1548–1551. Universidad Catolica Del Norte.

Suárez, M. and de la Cruz, R., 2000. Tectonics in the eastern central Patagonian Cordillera (45° 30 '-47° 30 ' S). *Journal of the Geological Society*, 157:995–1001. English Article SEP 5 J GEOL SOC.

Suárez, M, Marquez, M, and de la Cruz, R, 1997. Nuevas Edades K-Ar del Complejo El Quemado, a los 47°13'-47°22' S. In *VIII Congreso Geológico Chileno*, volume 2, pages 1552–1555. Universidad Catolica del Norte.

Suárez, Manuel and de la Cruz, Rita, 1996. Estratigrafia y tectonica de la zona sureste del Lago General Carrera (46°30'-47°lat. S.), Cordillera Patagonica, Chile. In Anonymous, editor, *XIII Congreso Geológico Argentino y III Congreso de exploracion de hidrocarburos.*, volume 13 of *Actas del Congreso Geológico Argentino*, pages 425–432. Asociación Geológica Argentina, Buenos Aires, Argentina. XIII Congreso Geológico Argentino y III Congreso de exploracion de hidrocarburos. Buenos Aires, Argentina. Oct. 13-18, 1996. LAT: S470000; S463000; LONG: W0713000; W0720000.

Townsend, M J, 1995. The paleogeographic evolution of the sedimentary Aysén Basin of Southern Chile during the Mesozoic. In *Abstracts, Andean Geosciences Workshop*. Kingston University.

USGS, 1999. Landsat 7 Enhanced Thematic Mapper Image, Path 231, Row 92, 22/8/99.

White, A J R and Chappell, B W, 1977. Ultrametamorphism and granitoid genesis. *Tectonophysics*, 43:7–22.

Wilson, M., 1989. *Igneous Petrogenesis*. Unwin Hyman, London, 1st edition.

Appendix A

Petrographic descriptions

A.0.1 Key:

Q: Quartz

A: Alkali Feldspar

P: Plagioclase Feldspar

F: Feldspathoids

CF: Crystal fragments

RF: Rock fragments

V: Vitric matrix

QF: Quartz fragments

RF: Rock fragments

FF: Feldspar fragments

* : analysed

Petrographic descriptions may contain abbreviations for plagioclase Anorthite percent determination methods such as: ML: Michel Levy Method, Section Ta: Section perpendicular to a, and C-a: Carlsbad-Albite twin method.

Also present are 'Plag' for plagioclase, 'cpl' and 'ppl' for cross and plane polarised light respectively, and mineral names may be shortened to their first syllable.

A.1 Basement Schists

Field Number	Formation:					
SCH4	Paleozoic Basement					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
663616	4835104					0
Final Rockname						
Tectonised marble.						

Microscopic textures (SCH4):
Medium grained well recrystallised granoblastic calcite marble, with slight shape preferred orientation of crystals, presumably deformation derived. Very few accessory minerals apart from minor quartz and some opaques.

Field Number	Formation:					
SCH4b	Paleozoic Basement					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
663616	4835104					0
Final Rockname						
Ankerite zone Calc-silicate schist.						

Microscopic textures (SCH4b):

Calcic Schist, mineralogy: quartz/albite feldspar/calcite/ankerite/epidote/chlorite/pyrite.

Schistosity of chlorite/?ankerite/epidote/anhedral opaque anastomoses around pods of calcite or quartz/calcite/feldspar. Also minor evidence of trace muscovite.

Feldspar dominant over quartz, with moderate to large 2v (40 to 70 ish) and occasional twinning, but difficult to determine type. Grains are anhedral mosaic, with intricate boundaries, often strained and occasionally twinned. RI agains epoxy: Fast and slow strongly below epoxy.

Yellow epidote/clinozoisite (Not zoisite, as yellow and has inclined extinction in some sections) , rhombohedral high RI ?ankerite and yellow-green to grass green pleochroic chlorite form anastomosing schistosity around mosaic feldspar/quartz/calcite pods and ribbons. Also blocky square pyrite porphyroblasts and anhedral, sometimes elongate, patches of opaque ?graphite. Chlorites are length fast, brown int colours and strongly coloured, so probably prochlorite to pseudothuringite.

Field Number		Formation:					
SCH5A *		Paleozoic Basement					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
673543	4822099		3	0	60	0	63
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
			25	10			
Other components:		Others:	Total:				
Calcite, epidote, etc.		2	100				
Final Rockname							
Altered andesitic sill.							

Microscopic textures (SCH5A):

Altered andesitic sill, with equigranular texture of subhedral framework of altered plagioclase with interstitial chloritised mafics, opaques and anhedral quartz.

Plagioclase is about 60% of the rock, subhedral and euhedral sericitised and murky crystals up to 0.5mm. Crystals may be replaced by albite/sericite/epidote/calcite, so some saussauritisation.

Chloritised mafics are about 25%, possibly after pyroxene or amphibole, but no discernable pseudomorphs of either. Interstitial to plagioclase, bright green pleochroic, blue in cpl.

Quartz is about 2–3%, sparse, interstitial anhedral crystals <0.2mm or void filling euhedral terminated crystals up to 3mm.

Opaques about 10%, euhedral blocky and oxidised magnetite, intergranular to plagioclase, up to 0.1mm.

Field Number	Formation:					
SCH3	Paleozoic Basement					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
661517	4837786					0
Final Rockname						
Quartz-Muscovite semi pelitic to pelitic Phyllite, slightly recrystallised by proximity to the Batholith						

Microscopic textures (SCH3):

Fine grained quartz/albite/mica/chlorite rock, with schistosity of alternating bands of quartz and mica/dissolution seam opaques. Dissolution seams are concentrated in micaceous layers, and vice versa. Dissolution seems more pronounced on steep limb of crenulations.

Quartz is very fine grained (sub0.05) granoblastic mosaic quartz, slight SPO due to dissolution on sides bounded by micas or dissolution seams, but no LPO. Later stage quartz veins are of mosaic quartz, slightly greater grainsize (.05 to0.4mm), and with some LPO from fringe orientated growth along vein margins. No feldspar in veins.

Murky, slighlty altered feldspar grains within mosaic quartz can be determined by RI and interference figure (2v high, 90 ish), but too small to determine accurate composition. Becke line test below quartz, so probably sodic plagioclase, probably Albite from 2v.

Chlorite is fine fibrous or platy crystals, intergranular to the quartz mosaic crystals, colourless or very pale green and anomalous blue in cross polars.

Muscovite is concentrated in the dissolution seam areas, colourless, sub parallel to solution seam direction, as fibrous or platy grains, often as fringes between or around quartz grains.

Some of the micas and chlorite show no strong orientation, and together with the mosaic nature of the quartz suggests this rock has been thermally annealed by the batholith.

Field Number SCH2		Formation: Paleozoic Basement					
Utm East 660592	Utm North 4842154		Q: 1	A: 10	P: 70	F: 0	Subtotal: 81
Cpx:	Opx:	Amph: 5	Chlorite:	Opaques: 3	Muscovite:	Biotite: 8	Olivine:
Other components: Epidote/apatite/etc.		Others: 3	Total: 100				
Final Rockname Tectonised and recrystallised biotite-hornblende gneiss. Texture looks like it may have been an granitoid lit par lit injection layer that has been heated, tectonised and recrystallised.							

Microscopic textures (SCH2):

Inequigranular rock with large crystals of sodic plagioclase (3–10mm), with intergranular fine mosaics of untwinned granoblastic feldspar (.1–1mm), with radial or poorly orientated sprays of red brown biotite and pale yellow to green pleochroic amphiboles. Perhaps some epidote, plus opaque sulphides, trace apatite. Chlorite present as alteration product.

Textures are reminiscent of a slightly tectonised granitic gneiss, with some fracturing of larger feldspar crystals. Probably annealed, though, to account for the finer mosaic texture of the smaller feldspars and amphiboles. Sprays of fine acicular pale amphibole, and perhaps epidote, are nucleated in radial clusters on many grain boundaries between feldspars, or in areas of smaller mosaic feldspar.

Fine grained mosaic feldspar has fast and slow below resin mounting, and 2v high, 80 or 90, so probably Low albite, perhaps up to Sodic Oligoclase, supported by occurrence of albite twins in some crystals.

Large albite-pericline twinned crystals look more like albite or sodic oligoclase. 2v is between 60–80, and RI is low, fast just below medium, Slow about the same, so probably Albite. Maybe fine grained mosaic k-spar appears to be replacing large albite crystals, and some large crystals are have faint blebs of low RI material, so may be slightly anti-perthitic.

Quartz is not present, or trace only. Proportions probably: Large Albite 30%, Groundmass albite 40%, Trace K-spar (5–10%) plus Biotite 8% and Amphibole 5%, others trace to 1%.

Field Number SCH2B-SCH2B'		Formation: Paleozoic Basement					
Utm East 660592	Utm North 4842154		Q: 25	A: 5	P: 60	F: 0	Subtotal: 90
Cpx:	Opx:	Amph: 5	Chlorite:	Opaques: 1	Muscovite:	Biotite: 4	Olivine:
Other components:		Others:	Total: 100				
Final Rockname Contact metamorphosed high greenschist facies or low amphibolite facies amphibolitic gneiss country rock and Tonalitic granitoid lit par lit injection layers, both recrystallised and metamorphosed by the Batholith.							

Microscopic textures (SCH2B-SCH2B'):

Sample SCH2B — Felsic band sample: Heterogranular quartz/feldspar/biotite/amphibole rock with large rounded feldspar crystals, in matrix of mosaic quartz and feldspar and poorly shape orientated sparse amphiboles and micas, sometimes in poor rosette patterns.

Amphibole is pale yellow-green pleochroic, stubby, prismatic crystals, probably hornblende group. Segregation layering is present, as felsic material and micas and ampihiboles are separated as gneissic schistosity.

Feldspars are low RI, anhedral or subhedral with occasional albite twinning. Low delta grain has Beta well below slow quartz and moderately below fast quartz, So sodic plagioclase below about An 20, and low delta grain against epoxy is slightly below it, so probably Albite, or very Sodic Oligoclase. 2Vs are 80–90 for albite twinned grains. Some plagioclase is myrmekitic, with quartz rods present. Maybe trace to 5% K-spar.

20–25% quartz, 60% Plagioclase feldspar, 5% Amphibole, 4–5%Biotite. Unlike the mafic bands, this rock has no apparent Lattice pref. Orientation in the quartz and feldspars. It appears well recrystallised, with a heterogranular mosaic texture. The large feldspars may indicate that it has been a granitic injection layer, which has since been thermally metamorphosed and recrystallised.

Sample SCH2B' — Mafic band sample: Heterogranular mosaic of dark green amphibole, feldspar and biotite, with common fine graine opaques and trace apatite. Amphibole has moderate shape preferred orientation, while feldspar has a poor lattice preferred orientation. Biotite also has shape preferred orientation. All parallel to banding in sample. Vein feldspar at about 5–10 degrees angle to the materix shape orientation still has the same lattice orientation, although vein biotite has an orientation more in keeping with growth as fringes on vein margin.

Amphibole is anhedral, with moderate SPO of elongated crystals. Mid to dark olive green, moderately pleochroic. Many larger crystals have internal core with many opaque inclusions, while small crystals or those grown in vein areas lack these inclusions, and crystals with inclusions have an outer inclusion free zone. Green actinolite or hornblende.

Feldspar is subhedral or anhedral mosaics, sometimes albite or crosshatch twinned. Albite twinned crystals have fast just below epoxy, slow just the same or equal. Looks like Albite or Sodic Oligoclase. 2v large.

About 60 to 65% Amphibole, 30% feldspar, 3–5% biotite.

A.2 Ibáñez Formation

A.2.1 Silicic Pyroclastic Rocks

Field Number	Formation:					
F9M *	Ibáñez tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
288074	4868214	23	7	70		100
Final Rockname						
Welded rhyolitic Ignimbrite.						

Microscopic textures (F9M):

Three similar sections, displaying vitroclastic and eutaxitic textures, 2–15% crystal and lithic contents, and similar alteration minerals. Middle and top appear more altered than the base.

Quartz: Sub0.2 to 3–4mm, 5%, rounded, embayed or fractured bipyramids.

Feldspars are Sub0.4 to 2mm, 15%-ish. subhedral-to euhedral or fractured. Sodic plagioclase, maybe sanidine or anorthoclase. Commonly sericitised/replaced by calcite. K-Spar present is probably sanidine, low 2v, ?replaced by calcite in many cases. Plagioclase is Albite or Oligoclase. Often sericitised.

Biotite: Trace-3%, up to 2mm, now altered to pseudomorphs of hematite, calcite, muscovite and leucoxene.

Lithics are angular, small (up to 6mm) altered/silicified felsitic rhyolite, spherulitic rhyolite, dacitic rock fragments, etc. 5–7%

Groundmass: About 70% of rock, Flattened and welded shards, replaced by calcite/sericite/muscovite, visible in cherty-felsitic devitrified ash matrix. Also hematite staining, and fine magnetite/ilmenite, altered to hematite and leucoxene. Pumice clasts flattened and attenuated, altered to sericite/calcite/hematite?zeolite.

Other minerals: Calcite, as replacement of shards and plagioclase. Leucoxene and hematite as alteration of mag/ilmenite and biotite. Maybe trace epidote. Chlorite ?trace, in groundmass as alteration product.

Field Number	Formation:					
CP67	Ibáñez tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
275339	4870746	24	12	64		100
Final Rockname						
Thickly bedded, moderately sorted coarse ashy vitric tuffs. Slightly thermally recrystallised/baked.						

Microscopic textures (CP67):

Baked or oxidised tuff, with common fine disseminated red hematite staining in reflected light, together with opaque patches of hematite and leucoxene as alteration of opaques and mafic lithic fragments.

Rock is moderately sorted coarse ash crystal and rock fragments, with occasional crystal, rock and pumice fragments up to 5–6mm, but most between 0.5 and 2mm.

Crystal fragments: 10% broken subhedral rounded beta-quartz fragments, between 0.1 and 2mm, most about 0.–0.3mm. 8% altered and partly sericitised sodic plagioclase, broken subhedral fragments, similar size range to quartz. Also 6% low 2v (20–40) Sanidine?, also similar size range to quartz fragments, and occasionally perthitic with exsolved plagioclase patches.

Lithic fragments are angular to sub rounded 1–10mm oxidised pilotaxitic andesitoids, with partial to complete replacement by hematite opaques. Again, most are0.5–2mm grain sizes, with occasional larger clasts. About 12%.

Pumice fragments are visible in ppl as irregular wispy fragments, with some vesicular texture visible, and recrystallised to felsitic or quartz mosaic in cpl, about 25%, 1mm to 3–4mm.

All coarse ashy material and pumice/lithic fragments are matrix supported in fine grained devitrified felstitic matrix, about 41% of rock.

Field Number	Formation:					
F11M *	Ibáñez tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
288173	4869185	40	5	55		100
Final Rockname						
Welded rhyolitic ignimbrite.						

Microscopic textures (F11M):

More crystal and lithic rich thin section than basal sample.

Quartz is fractured and rounded/embayed bipyramids, up to 3mm, about 15%.

Feldspars are almost all completely sericitised or replaced by calcite. 25%.

Biotite occurs as euhedral broken cleavage fragments and 'booklets', generally altered to muscovite in optical continuity with the original biotite and opaque leucoxene occurs along cleavage plains. (Trace to 1%)

Groundmass (55%) is still devitrified to felsitic material, shard textures are less preserved than in the basal sample. Larger shards are replaced by quartz/feldspar or by sericitic muscovite. Common secondary patches of calcite, more red hematite stained patches, and some patches of quite strongly recrystallised material to quartz-feldspar mosaic. Greater destruction of shard textures may indicate more welding.

Pumices are still sparse, well flattened fiamme, altered to mix of calcite and sericite, seldom more than 5mm long. Some have devitrified to spherulitic textures, but are now replaced partly by sericite and calcite.

Lithic fragments are present as oxidised dark red or opaque intermediate volcanic rockfragments, larger than basal sample, with one 10x15mm lithic of oxidised andesitoid, and some quartz/feldspar mosaic recrystallised rhyolitoid. (1–5%.)

Field Number	Formation:					
F11B *	Ibáñez tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
288173	4869185	37	1	62		100
Final Rockname						
Welded rhyolitic ignimbrite.						

Microscopic textures (F11B):

Quartz, Feldspar, altered biotite and lithics in vitroclastic altered groundmass, shards devitrified but texture preserved. Calcite as alteration, plus ?muscovite.

Quartz is fractured and rounded/embayed bipyramids, up to 3mm, about 20%.

Feldspars: 10–15%, up to 1.5mm. Rounded subhedral or fractured. Sodic plagioclase and ?Sanidine K-spar. Plagioclase is often sericitised or replaced by calcite.

Biotite occurs as euhedral broken cleavage fragments and 'booklets', generally altered to red and orange semi opaque iron oxides, leucoxene and some muscovite. 2%.

Groundmass is about 62% of rock, partially or wholly devitrified to felsitic material, but shard textures are still well preserved by grain size variations in the felsitic material. Larger shards are replaced by quartz/feldspar or by sericitic muscovite. Common secondary patches of calcite.

Some very fine opaques. Shard wrap-around textures with phenocrysts are visible. Trace ?Epidote. Pumices are sparse, well flattened fiamme, altered to mix of calcite and sericite, seldom more than 5mm long.

Other minerals: Leucoxene as opaqe, and alteration of biotite. Calcite as void filling, and replacement of feldspars, fiamme.

Lithic fragments are present as oxidised dark red or opaque intermediate volcanic rockfragments, from0.5-3-mm, (up to 5cm in hand spec) angular, about 1%. Some are rhyolitoid.

Field Number	Formation:					
F9T *	Ibáñez tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
288074	4868214	23	7	70		100
Final Rockname						
Welded rhyolitic Ignimbrite.						

Microscopic textures (F9T):

Three similar sections, displaying vitroclastic and eutaxitic textures, 2–15% crystal and lithic contents, and similar alteration minerals. Middle and top appear more altered than the base.

Quartz: Sub0.2 to 3–4mm, 5%, rounded, embayed or fractured bipyramids.

Feldspars are Sub0.4 to 2mm, 15%-ish. subhedral to euhedral or fractured. Sodic plagioclase, maybe sanidine or anorthoclase. Commonly sericitised/replaced by calcite. K-Spar present is probably sanidine, low 2v, ?replaced by calcite in many cases. Plagioclase is Albite or Oligoclase. Often sericitised.

Biotite: Trace-1%, up to 2mm. now altered to pseudomorphs of hematite, calcite, muscovite and leucoxene.

Muscovite occurs as alteration product of biotite, Trace-2%

Lithics are angular, small (up to 6mm) altered/silicified felsitic rhyolite, spherulitic rhyolite, dacitic rock fragments, etc. 5–7%

Groundmass: About 70% of rock, flattened and welded shards, replaced by calcite/sericite/muscovite, visible in cherty-felsitic devitrified ash matrix. Also hematite staining, and fine magnetite/ilmenite, altered to hematite and leucoxene. Pumice clasts flattened and attenuated, altered to sericite/calcite/hematite?zeolite.

Other minerals: Calcite, as replacement of shards and plagioclase. Leucoxene and hematite as alteration of magnetite/ilmenite and biotite. Maybe trace epidote. Chlorite ?trace, in groundmass as alteration product.

Field Number	Formation:					
F9B *	Ibáñez tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
288074	4868214	23	7	70		100
Final Rockname						
Welded rhyolitic Ignimbrite.						

Microscopic textures (F9B):

Three similar sections, displaying vitroclastic and eutaxitic textures, 2–15% crystal and lithic contents, and similar alteration minerals. Middle and top appear more altered than the base.

Quartz: Sub0.2 to 3-4mm, 5%, rounded, embayed or fractured bipyramids.

Feldspars are Sub0.4 to 2mm, 15%-ish. subhedral-to euhedral or fractured. Sodic plagioclase, maybe sanidine or anorthoclase. Commonly sericitised/replaced by calcite. K-Spar present is probably sanidine, low 2v, ?replaced by calcite in many cases. Plagioclase is Albite or Oligoclase. Often sericitised.

Biotite: Trace-1%, up to 2mm. now altered to pseudomorphs of hematite, calcite, muscovite and leucoxene.

Muscovite occurs as alteration product of biotite, Trace-2%

Lithics are angular, small (up to 6mm) altered/silicified felsitic rhyolite, spherulitic rhyolite, dacitic rock fragments, etc. 5–7%

Groundmass: About 70% of rock, flattened and welded shards, replaced by calcite/sericite/muscovite, visible in cherty-felsitic devitrified ash matrix. Also hematite staining, and fine magnetite/ilmenite, altered to hematite and leucoxene. Pumice clasts flattened and attenuated, altered to sericite/calcite/hematite?zeolite.

Other minerals: Calcite, as replacement of shards and plagioclase. Leucoxene and hematite as alteration of magnetite/ilmenite and biotite. Maybe trace epidote. Chlorite ?trace, in groundmass as alteration product.

Field Number	Formation:					
WI7 *	Ibáñez tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
277920	4863330					0
Final Rockname						
Silcified and mineralised rhyolitic tuff incorporated into fault breccia.						

Microscopic textures (WI7):

Fine grained cherty brecciated tuff/tuffaceous sediment, with angular 1–10mm clasts of fine felsitic material, recrystallised and devitrified, but with occasional remnant shard textures visible in some clasts, and alteration of calcite and fine blue-green disseminated chlorite.

Secondary silicification has cemented clasts and void space with cherty quartz cement, and brown iron oxides are common as alteration of mafics and as dusty lining on clasts.

Occasional clast of pilotaxitic andesitoid occurs, with sericite/calcite replaced feldspars and bright green interstitial chlorite alteration of feldspars, and secondary pyrite cubes.

Field Number	Formation:					
CP86	Ibáñez tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
278950	4870020	7	40	53		100
Final Rockname						
Rhyolitic breccia or block and ash tuff.						

Microscopic textures (CP86):

This rock is fragmental, with crystals and rock fragments in a fine felsitic matrix. Crystals include sodic plagioclase, quartz, opaques altered to leucoxene, while rock fragments are of either spherulitic or felsitic rhyolitic material.

Felspars are altered, to sericite, clay or calcite, partly rounded subhedral or fractured crystals, mostly less than 1.5mm. From remnant twins, probably sodic plagioclase. 5%.

Quartz is sparse as crystal material, occuring as some small, rounded and fractured bipyramids. 2%.

Rock fragments are angular, up to 5mm, composed of felsitic or recrystallised spherulitic rhyolite, now recrystallised to poikilomosaic quartz. Spherulite fragments are broken, feathery sectors and fragments of spherulites, aud have clearly not grown in the rock they now occupy. Some have partly recrystallised to poikilomosaic quartz, however. Rock fragments about 35–40%.

Matrix is fine felsitic textured material, with some ?pumice, but mostly felsitic material and fine grained fractured and crushed crystal fragments, spherulite fragments, etc. Little or no evidence of shard textures or fiamme texture. Partly recrystallised in places to mosaic quartz in veins and cavities. Common goethite/leucoxene as opaques. About 53% of rock.

Field Number	Formation:					
F8B	Ibáñez tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
287390	4869125	10	20	70		100
Final Rockname						
Possible basal surge rhyolitic tuffs associated with Coulee Lava from Frontier Dome?						

Microscopic textures (F8B):

Altered tuff, with quartz/feldspar/biotite crystals in a felsitic, devitrified matrix.

Quartz: 1-5% Subhedral-euhedral rounded bipyramids, up to 2mm, and irregular fragments, perhaps partly recrystallised/overgrown from matrix.

Feldspars: 5% or less, up to 3mm, Subhedral fractured sodic plagioclase, sericitised. Maybe some ?perthitic or unmixed K-spar.

Biotite: Trace, occasional small0.2mm to0.5mm biotite flake, green-brown pleochroic. Not too altered, some chloritised.

Other minerals: Leucoxene and hematite opaques. Maybe some groundmass zeolite, but doubtful.

Groundmass: Fine grained felsitic textured devitrified material with very faint vitroclastic and pumice textures, also with patches, networks and seams of fine muscovite alteration.

Lithics: Angular red-brown fragments of spherulitic rhyolite are common, generally 1mm or less. Also 1 large 5mm fragment of intermediate ?dacitoid trachytic textured fragment with well developed quartz groundmass poikilomozaically enclosing pilotaxitic feldspar microphenocrysts. Some small cherty felsic volcanic fragments.

Devitrified ashy groundmass & pumices: 70%. Crystal Fragments: 10%. Lithic/rock Fragments: 20%.

Field Number	Formation:					
F11T *	Ibáñez tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
288173	4869185	51	3	46		100
Final Rockname						
Welded rhyolitic ignimbrite.						

Microscopic textures (F11T):

Similar to middle sample, with much reddish hematite staining of groundmass and pumices. More pumice fiamme, some of which are devitrified to spherulites and later coarse quartz mosaic recrystallisation. Sericitisation very common, biotite altered to muscovite and leucoxene in same manner as middle samples.

Quartz is fractured and rounded/embayed bipyramids, 1–5mm, about 20%. Larger crystals than base and middle of this ignimbrite.

Feldspars are still badly sericitised or replaced by calcite. More crystal rich than middle or base, with up to 30% feldspars. Crystals are broken and fractured euhedral sodic plagioclase, albite-carlsbad twinned, ML readings: 17, 7, 8, 16.5, 20, 7.5, 8.5, 20 degrees give An28%, Calcic Oligoclase. Some low RI carlsbad twinned crystals may be Sanidine.

Biotite still occurs as euhedral broken cleavage fragments and 'booklets', altered to muscovite in optical continuity with the original biotite and opaque leucoxene exsolved along cleavage plains. (Trace to 1%)

Groundmass, about 46% of rock, is still devitrified to felsitic material, shard textures are less preserved than in the basal sample. Larger shards are replaced by quartz/feldspar or by sericitic muscovite. Common secondary patches of calcite, and red hematite stained patches, and some patches of quite strongly recrystallised material to quartz-feldspar mosaic. Greater destruction of shard textures may indicate more welding. Pumices slightly more common than lower samples, about 10%, well flattened fiamme, up to 10mm long, devitrified to radial or elongate spherulites but are now replaced partly by sericite and calcite.

Lithic fragments are present as quartz/feldspar spherulitic rhyolitoids and devitrified tuff fragments, up to 4mm in thin section, 3%.

Field Number	Formation:					
PI55	Ibáñez tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
271050	4873700	62	30	8		100
Final Rockname						
Calcite/sericite cemented crystal and lithic tuff.						

Microscopic textures (PI55):

Black to purple black, pinch and swell bedded medium through to coarse sandy, moderately sorted sub-angular to angular volcaniclastic (feldspar and rock fragments) clast supported matrix poor sandstone.

Clasts are altered and often replaced by calcite. Occasional flattened pumice fragments, but no pervasive vitroclastic texture. Clasts well imbricated, some evidence for solution seams parallel to imbrication/bedding orientation.

Clast population, looks about 60% sericitised/calcite replaced feldspar, 1–2% quartz fragments, 1–2% pumice fragments, 30% rock fragments and opaques, plus 3–6% calcite/zeolite/sericite matrix after ashy matrix?

Field Number	Formation:					
L20α *	Ibáñez tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
280500	4859600	32	5	63		100
Final Rockname						
Rhyolitic Ignimbrite.						

Microscopic textures (L20α):

Pumice and crystal rich rock, with large devitrified pumice fiamme, quartz, plagioclase, lithic fragments and biotite, in eutaxitic texture in devitrified matrix of ash and fine crystal fragments.

Rock is crystal rich, being about 25–35% quartz/feldspar/biotite crystals and crystal fragments. Pumice fiamme are probably about 20%, and lithic fragments about 5%, with about 30–35% devitrified ashy matrix. Fiamme texture and remnant shard textures are well developed and partially flattened, but not with strong wrap-around textures, so welding not particularly advanced — sintered rather than strongly welded.

Quartz is broken and embayed/rounded bipyramids, often with adhering whisps of devitrified pumice. 10–15%, up to 5mm crystals.

Plagioclase is euhedral and subhedral broken crystals, sometimes broken glomeroporphyritic crystals. Crystals are up to about 4mm, 8–9%. Patchy sericitisation and alteration of some cores to calcite or sericite is common. ML on twinned crystals: 9, 20.5, 6, 17.5, 8.5, 14.5, 5, about An 29–30%, Calcic Oligoclase. K-spar is present in spherulites grown in devitrified pumices, and low RI untwinned feldspar crystal fragments have 2v about 30, RI fast and slow, well below epoxy, probably sanidine. Sanidine crystal fragments: 1%.

Biotite crystals are occasional cleavage flakes and booklets, oxidised and rimmed with semi-opaque hematite and in some cases slightly chloritised or green-brown pleochroic. Less than 1mm size, about 1–2%.

Lithic fragments are usually angular fragments of oxidised silicic volcanic rocks, stained with hematite and recrystallised into quartz mosaic over original felsitic texture. 1–2mm or less, 5% ish.

Matrix is devitrified and oxide stained vitroclastic material, with common whisps of pumice, some up to 5cm long, also devitrified to spherulitic and felsitic textures, in some places partly sericitised or replaced with calcite. Shard textures and pumice textures visible in ppl, but alteration and devitrification textures visible in cpl.

Field Number	Formation:					
PI29	Ibáñez tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
273300	4871125	23	5	72		100
Final Rockname						
Rhyolitic Ignimbrite.						

Microscopic textures (PI29):

Quartz: g/mass to 5mm phenocrysts, 15%, Rounded, embayed and fractured, some euhedral bipyramids.

Feldspar: Altered, murky, up to 2.5mm, 10% Plagioclase ML: 12.5, 12, 16.5, 16, 11,5.5, 16, so Albite or Oligoclase, RI suggests Albite. Sericitised.

Biotite 3%, up to 2mm, green brown pleochroic, altering to Chlorite.

Other minerals: Calcite in g/mass, voids and altering feldspars. Trace zircon, maybe some clays (unusual murky opaques. Magnetite, altered, trace opaque.

Groundmass: about 70%, felsitic material, with well developed shard textures but recrystallised to felsitic and quartz mosaic material in cpl. Pumices are flattened, extensively recrystallised into quartz, calcite, sericite.

Lithics about 5%, Some large, (30mm hand spec.) rhyolitic tuffs, dacitic rock fragments with pilotaxitic feldspars and poikilomosaic quartz groundmass.

Field Number	Formation:					
PI30C	Ibáñez tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
273175	4871100	26	3	71		100
Final Rockname						
Rhyolitic bedded tuff.						

Microscopic textures (PI30C):

Quartz:0.4–4mm, 10%. Mostly fractured, subhedral, also rounded aud embayed.

Feldspar:0.2–3mm, 10–15% Altered, Albite. Subhedral and euhedral crystals, up to 4mm.

Other minerals: Calcite, as alteration of feldspars and as void-fill/replacement of groundmass. Apatite as inclusions within biotite, Zircon (with haloes,) in biotite. Biotite Trace to 1%,0.2 to 1mm, Green-brown pleochroic, altering to chlorite. Magnetite as opaque, trace.

Groundmass about 60%, recrystallised felsitic material with ghost shard textures visible in ppl. Shards in Cpl are quartz-feldspar mozaic. Pumices are about 10–11%, altered to felsitic material, and calcite, sericite.

Lithic fragments are about 1-3%, spherulitic rhyolite, and pilotaxitic to poikilomosaic recrystallised dacite.

Field Number	Formation:					
PI33	Ibáñez tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
273000	4871180	23	3	74		100
Final Rockname						
Rhyolitic tuff						

Microscopic textures (PI33):

Quartz:0.5 to 5mm, 10%. Anhedral shattered grains, to embayed, euhedral bipyramids. Some grains have cherty overgrowths and overgrown dust rims.

Feldspar: 12% Altered, murky oligoclase/albite. Plagioclase within relic pumices is often glomeroporphyritic, euhedral or skeletal. Altered to sericite.

Other minerals: Secondary Calcite,in some pumice fiamme, and as alteration of feldspar. Also sericitic alteration of feldspar. Maybe 1% Biotite pseudomorphed by opaque Fe-oxides. Maybe also trace amphibole, pseudomorphed by opaque alteration products.

No obvious lithic fragments in thin section, 1–3% small 2mm or less altered mauve lithics in hand specimen.

Groundmass about 70–74%, Recrystallised felsitic material, with ghosts of glass shards visible in ppl, showing some wrap-around textures on crystals. Occasional microphenocrysts of feldspar, muscovite, opaques visible. Becke lines indicate multiple minerals, probably Quartz/feldspar in felsitic material. Felsitic Quartz/Feldspar in pumice relics is coarser than in the groundmass, but feldspars are still altered. Pumice fragments, trace. Uniformly granular recrystallised patches with ragged edges and euhedral crystals held within.

Field Number	Formation:					
PI34B	Ibáñez tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
272918	4871350	15	30	55		100
Final Rockname						
Rhyolitic Ignimbrite.						

Microscopic textures (PI34B):

Quartz: Sub 1.5mm, 1–5%

Feldspars are about 10%, Albitised Plagioclase and K-spar. K-spar is Sanidine, 2v small, RI strongly below epoxy. Plagioclase is Albite, (RI fast and slow slightly below epoxy), altered, sericitised, some replacement by calcite.

Other minerals: Calcite replacing feldspars, some reddish hematite. Possibly murky clays in the feldspars. Chlorite common as alteration product of mafics and in G/mass.

Groundmass is about 55%. Fine grained felsitic groundmass with occasional coarser patches of felsitic material and muscovite perhaps representing altered pumice fiamme.

Lithics: Sub 5mm to 10mm, 25–30%, altered rhyolitic, dacitic, mafic volcanics, some cherty metamorphic quartzite.

Field Number	Formation:					
PI36A	Ibáñez tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
272275	4871750	16	5	79		100
Final Rockname						
Rhyolitic Ignimbrite.						

Microscopic textures (PI36A):

Quartz: Trace-1% as phenocrysts, but common in Groundmass.

Feldspars: Sanidine, Untwinned or Carlsbad twinned, RI below medium, 2v small.?5% Plagioclase: Approx 10% Plag. ML: 17.5,16,14,9.5,8,2.5,5 so Albite or Oligoclase An 23–4. Some synneusis twins present. Fast and slow RI below medium, so Probably Albite or Albitised.

Other minerals: Trace Epidote, Calcite as cavity infill, some Fe Oxide staining. Biotite, ?Trace, now altered. Muscovite, as sericitic alteration, in some rock fragments and in groundmass. Trace chlorite in groundmass, also present as alteration product of ?Biotite.

Groundmass: 79% of rock, devitrified, fine felsitic texture with ghost glass shards visible in PPL, but recrystallised to coarse felsitic material in CPL. Plus fine opaques. Coarse felsitic textured patches may define relic devitrified and rexllised pumices.

Lithics, about 5%, Rock fragments are felsitic and spherulitic rhyolites, pilotaxitic or poikilomosaic recrystallised dacitic volcanic fragments, quartzite, and spherulitic devitrified obsidian with microlites.

Field Number	Formation:					
PI43T *	Ibáñez tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
271625	4871575	36	5	59		100
Final Rockname						
Rhyolitic Ignimbrite						

Microscopic textures (PI43T):

Quartz: up to 2mm, 10%, rounded, embayed and fractured.

Feldspars about 25%, some Sanidine, up to 2mm, 10%, and sodic plagioclase, sericitised, about 15%.

Biotite: 1%, green-brown, very altered and changing to chlorite.

Other minerals: Trace Epidote, granular and radial patches or sprays. Magnetite, Trace, as sub 1mm crystals or in groundmass.

Groundmass: Approx 39%. Detrital, recrystallised glass shards, devitrified to felsitic material, and chlorite, opaques. Also Pumice, 2–8mm, 15–20%. Recrystallised into coarse felsitic texture.

Lithics: Up to 10 mm, 5%. Fragments of ignimbrite, andesitoid, ?schist.

Field Number	Formation:					
PI43B *	Ibáñez tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
271625	4871575	15	5	80		100
Final Rockname						
Rhyolitic Ignimbrite						

Microscopic textures (PI43B):

Crystal and lithic poor tuff, with sparse crystals of quartz, sodic plagioclase and altered biotite, and occasional schist lithic fragments.

Quartz is subhedral broken and embayed beta quartz bipyramids, ranging from sub0.1mm groundmass fragments up to 3–4mm rounded and embayed subhedral bipyramids. About 5–6%, sometimes in clusters along fiamme-fabric/bedding imbrication of rock.

Feldspar is altered, sericitised sodic plagioclase, albite carlsbad twinned subhedral and fractured crystals, up to 2–3mm, about 8%. Fast and slow RI well below epoxy, so Albite plagioclase.

Biotite occurs as sparse cleavage flakes or booklets, and is altered to greenish chlorite or muscovite/chlorite mix with exsolved leucoxene along cleavage planes. Up to 1mm, trace to 1%.

Lithic fragments are sparse, 5% or less, angular pilotaxitic or porphyritic andesitoid to dacitoid volcanic rocks, sometimes with quartz mosaic poikilomosaic groundmass, oxidised and hematite stained. Also fragments of vitroclastic welded tuff and rounded fragments of green schist facies chlorite and muscovite schist (quartz/albite/chlorite or quartz/albite/muscovite). 1–6mm in range, avg 2mm or less.

Groundmass is 80% of the rock, about 5% sericite and calcite replacing pumice fragments, and otherwise fine grained felsitic textured devitrified ash, with ghost shard textures visible in ppl. Patches of sericite, pale to moderate green chlorite and calcite occur as occasional alteration or void filling.

Field Number	Formation:					
PI43δ	Ibáñez tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
271625	4871575	51	1	48		100
Final Rockname						
Blue indurated thinly bedded sorted medium to very coarse sandy Quartz/feldspar Crystal Tuffs/tuffaceous sandstones.						

Microscopic textures (PI43δ):

Moderately sorted, anhedral to subhedral angular quartz, feldspar, minor biotite, clast supported, with sparse matrix of felsitic material, some recrystallised quartz, calcite void filling.

Quartz: Large, up to 3mm, 30%. Mostly rounded and embayed, fractured bipyramids, some also as fine euhedral diagenetic? Growth in groundmass and as rims.

Feldspars:0.2–3mm, 20%, mostly Albite or Oligoclase, Altered.

Other minerals: Biotite, Trace to 1%, up to 2mm. Green pleochroic, ?altering to serpentine/chlorite, with exsolution of opaqes along cleavage, perhaps leucoxene.

Groundmass: Matrix Approx 45–48%. Rock is matrix poor, with most grains clast supported. Some void space filled with calcite, otherwise matrix is fine grained felsitic material, occasional leucoxene opaque, and fine platy/sericitic crystals of ?muscovite.

Lithics: 1% or trace only. Quartzite fragments, or quartzvein fragments, with mozaic texture remeniscent of quartz ribbons. Some have epidote.

Field Number	Formation:					
PI43γ	Ibáñez tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
271625	4871575					0
Final Rockname						
Mauve, crystal rich, poorly sorted, matrix supported rhyolitic tuffaceous medium to coarse sandstone						

Microscopic textures (PI43γ):

Quartz:15%. Up to 3mm. Subhedral, embayed, rounded and fractured fragments of Beta Quartz bipyramids.

Feldspar: 20%,0.2–2mm. Mostly Albite, or Albitised, murky alteration, perhaps clay/sericite. Subhedral and fractured.

Biotite 1–5%, up to0.8mm, green-pleochroic, altering and exolving leucoxene opaques along cleavage planes. Also altering to ?hematite, and perhaps to chlorite/muscovite/leucoxene mix.

Other minerals: Calcite, replacing feldspars and as void-fill. Dominant opaque in matrix is leucoxene. Trace Epidote as alteration of Feldspars.

Groundmass: 50–55% Fine felsitic material, with coarser patches of Quartz-feldspar pseudomorphing glass shards. Remnant vitroclastic and eutaxitic textures occasionally visible. Patches of Calcite, Hematite occur. Also felsitic altered and partly crushed pumices. Pumices contain ghost vesicle texture, and fine plates of muscovite.

Lithics: Trace. Cherty altered rhyolitic fragments occur.

Field Number	Formation:					
PI43M *	Ibáñez tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
271625	4871575	36	15	49		100
Final Rockname						
Rhyolitic Ignimbrite.						

Microscopic textures (PI43M):

Crystal and lithic rich tuff, with quartz, sodic plagioclase and schist lithic fragments in a matrix of partly sericite/chlorite replaced felsitic devitrified ash/glass shards.

Quartz: 15%, 5mm max, embayed, fractured bipyramids.

Feldspar: About 20%, albite and carlsbad twinned, moderate to large 2v, RI well below epoxy. Crystals are up to 3mm, subhedral and fractured, partly sericitised. Mostly Albite-carlsbad twinned high albite, perhaps some sanidine.

Biotite: 1%, altered, green-brown pleochroism. Chlorite present as alteration product of biotite, and in cavity infill.

Groundmass: 45–49% felsitic material with common secondary sericite, chlorite, with ghost impressions of recrystallised glass shards. Secondary calcite as cavity infill and alteration.

Lithics: 15%, Dominant lithics are quartz>albite>muscovite xenoliths, presumably underlying country rock. Also Chlorite>Muscovite>Quartz>Felds greenschists and quartzite fragments. Some andesitoid rock fragments also.

Field Number	Formation:					
L20 *	Ibáñez tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
280561	4859650	40	3	57		100
Final Rockname						
Welded and devitrified rhyolitic ignimbrite.						

Microscopic textures (L20):

Similar ignimbrite to L20α, but with markedly less pumice, and more devitrified groundmass. Biotite is less altered, but feldspars are more altered, clayey and sericitic.

Rock is less crystal rich, about 30% quartz/feldspar/biotite crystals and crystal fragments. Pumice fiamme are less common than the upper sample (20 α), only 5–10% or less, while lithic fragments are at the same level, about 5–10%, with about 40–50% devitrified ashy matrix. Fiamme texture and remnant shard textures are less well developed and flattened, with stronger wrap-around textures, and more advanced/pervasive devitrification and recrystallisation, perhaps suggesting stronger welding to glass that then devitrified.

Quartz is broken and embayed/rounded bipyramids, up to 5mm crystals, about 5–10%.

Feldspars are euhedral and subhedral broken crystals, sometimes broken glomeroporphyritic crystals. Crystals are up to about 4mm, 20%. Most are sericitised, and it is not feasible to identify plagioclase from crystalline angles. Most plagioclase remnants have RI suggestive of Albite or albitised.

K-spar occurs as low RI untwinned feldspar crystal fragments may also be k-spar, 5% or less. Also, as with L20α, K-spar is present in spherulites grown in devitrified pumices.

Biotite crystals are occasional cleavage flakes and booklets, 1.5mm max size, about 5%. Less altered than L20α, but some grains are still altered to hematite. Biotite is red-brown.

Lithic fragments are less common, but similar types to L20α, angular fragments of oxidised silicic volcanic rocks, stained with hematite and recrystallised into quartz mosaic over original felsitic texture. Also occasional granophyric quartz/feldspar intergrowth fragment. 1–2mm or less, 3%.

Matrix is about 57%, devitrified and oxide stained vitroclastic material, less pumices than L20α, devitrified to spherulitic, felsitic and patchy incipient poikilomosaic quartz textures. Shard textures and pumice textures just visible in ppl, but alteration and devitrification textures visible in cpl. This rock has a more devitrified groundmass, with better wrap around textures and more pervasive devitrification, perhaps indicative of greater welding. Not surprising due to its location in the columnar zone of the ignimbrite.

Field Number	Formation:					
PI51	Ibáñez tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
270468	4873521	32	10	58		100
Final Rockname						
Rhyolitic Tuff.						

Microscopic textures (PI51):

Crystal fragments, rock fragments and pumices matrix supported in fine felsitic devitrified ash.

Quartz: 15%,0.2–2mm, mostly subhedral, embayed or rounded grains. Often fractured. Also present in coarser devitrified shards in groundmass.

Feldspars: 15%. Up to 2mm, Subhedral, fractured grains. Sodic Plagioclase and K-spar (Sanidine). Often altered, replaced with calcite/sericite mix. About 10% plag, 4–5% Sanidine.

Plagioclase with Combined Ab-C twins give either An5% or An30%. RI is below glue, so probably An5% ish, so Albite or albitised. Some plagioclase has patchy replacment or exsolution of K-spar along cleavage planes and fractures, also K-spar outer rims occur.

Biotite is about 1% to trace. Altered (usually to chlorite/leuxcoxene/muscovite). Was probably green-brown. Also muscovite, trace, as sericitic alteration of feldspars and as alteration of biotite. Also present as fine plates in groundmass. Chlorite trace, as alteration of biotite, and as patches within g/mass aud pumices.

Other minerals: Leucoxene as common opaque. Possibly minor epidote. Also patches of reddish semi opaque ?hematite. Calcite as replacement of feldspars and as patches in groundmass. Opaques up to 1%

Groundmass: Devitrified fine felsitic material, leucoxene opaques, hematitic iron staining, with networks and clots of muscovite plates, chlorite, and ghosted vitroclastic texture in some places. Glass shards mainly replaced by quartz/feldspar mozaic, quartz dominant. Partially crushed pumices are devitrified, ragged terminations, also strongly sericitised to fine platy muscovite with some chlorite.

Lithics about 10%, including rhyolitoids, coarsely crystalliue Quartz/albite/muscovite/chlorite schists, intermediate pilotaxitic volcanics, ofteu oxidised red with hematite common. Most 5mm or less.

Field Number	Formation:					
PI61A	Ibáñez tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
271430	4873285	24	1	75		100
Final Rockname						
Rhyolitic tuff.						

Microscopic textures (PI61A):

Quartz/Feldspar/Biotite/lithics and pumice are matrix supported in matrix of devitrified but classic vitroclastic material.

Quartz: 10%,0.25–3mm. Large, rounded subhedral grains, embayments and fractures common. Rounded, euhedral embayed grains occur within pumices, and also occurs as fine, cherty mosaics iu devitrified pumice and groundmass.

Feldspars: 10%, 0.25–1.5mm. Altered, fractured subhedral crystals, probably dominated by Sodic Plag. Plagioclase 7% 0.25–1.5mm Subhedral and occasioual euhedral grains. Some sericitic alteratiou. RI indicates Albite. Kspar, 3%, rounded or broken subhedral crystals, less altered than albite, moderate 2v (40 ish), some carlsbad twinning. Probably Sanidine.

Biotite common, 3–4%, altered to opaque hematite and leucoxene with some muscovite. Euhedral booklets and cleavage flakes, 0.2–1mm. Trace Calcite. Hematite and leucoxene as opaques in g/mass and in altered biotites.

Groundmass: 50–60% Devitrified cuspate glass shards in fine brownish devitrified groundmass. Some traces of sericitic mica, glass shards devitrified to quartz/feldspar mozaic, with anhedral quartz, some euhedral feldspar termiuations, perhaps some zeolites too.

Pumices 15% flattened, devitrified, ragged terminations. Devitrifed into quartz/feld/sericite mozaic, also some calcite patches. Contain euhedral rounded and embayed quartz, plus biotite ps/morphs and albite phenocrysts.

Lithics are Trace-1%, rounded fragmeuts of felsitic rhyolite and intermediate andesitoid.

Field Number	Formation:					
F23 *	Ibáñez tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
287770	4869250	25	5	70		100
Final Rockname						
Welded rhyolitic ignimbrite.						

Microscopic textures (F23):

Ignimbrite with crystal phases of Quartz, Plagioclase, altered biotite, opaques aud groundmass of recrystallised vitroclastic texture and crystal/pumice fragments.

Quartz is broken and rounded/embayed bipyramids, about 12%.

Feldspar crystals are euhedral to subhedral fractured crystals, slightly altered with murky brown patches and some sericite. Most are sodic plagioclase, with albite-carlsbad twinning. Section A gives: 14 degrees, An% close to zero, so Albite. RI fast and slow well below epoxy supports this. Some low RI untwinned or carlsbad only twinned crystals have 2v low, about 20, so some Sanidine present. Total feldspars 12%, about 9% albite, 3% sanidine.

Biotite is altered to muscovite, opaque white leucoxene and hematite Trace to 1%.

Lithic fragments are rare, with the occasional 2–3mm angular to rounded fragment of rhyolitic tuff or oxidised andesitoid. 2–5%.

Groundmass is about 70% of rock, recrystallised to felsitic texture, or some quartz/zeolite formation in groundmass. Shard textures sometimes plastically deformed, but not strongly welded. Pumice fiamme, about 20% of groundmass, are altered to sericitic material plus or minus chlorite, and have remnants of recrystallisation spherulites.

Field Number	Formation:					
P164	Ibáñez tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
272570	4873165	22	18	60		100
Final Rockname						
Lithic Tuff with granule and small pebble size lithics.						

Microscopic textures (PI64):

Crystals and lithics are matrix supported in felsitic devitrified ash and flattened pumice fiamme. There is some evidence for ?dissolutions seams.

Quartz: 0.2–2mm. 7% Subhedral, rounded, embayed or fractured. Also present as fine mozaic with sericitic mica and feldspars in devitrified pumice fiamme.

Feldspars: 0.2–3mm. 10–15% Mostly appear to be sodic plagioclase and some K-spar, with some High sanidine in alkaline volcanic lithics. Plagioclase has Rl fast & slow below medium, so Albite or Albitised. (Fast, well below medium, slow just below.) Some sericitisation.

Other minerals: ?Trace Epidote. Calcite common as replacement of Feldspars with sericite and ?Epidote. Also chlorite alteration.

Groundmass: 50% Felsitic material with rare preserved glass shards. Common fine grained sericitic mica and chlorite as patches, veins and networks. Fine equigranular leucoxene occurs, as does some ironstaining around crystal rims and opaques. 10% Large 1–30mm, devitrifed and flattened lensoidal pumices, often sericitised with small mica flakes.

Lithics: 18% 1–10mm Lithic fragments include oxidised plagiophyric andesitoids, and porphyritic dacitic and rhyolitic fragments with felstic and poikilomosaic quartz/feldspar recrystallised groundmass. Some of the andesitoids are blebby, rounded and may be cognate magmatic blebs from a bimodal eruption.

Field Number	Formation:					
GA10C	Ibáñez tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
287300	4871750	3	7	85		95
Other components:	Others:	Total:				
Calcite/sericite	5	100				
Final Rockname						
Rhyolitic pumice flow tuff/surge tuff.						

Microscopic textures (GA10C):

Pumice flow tuff, with 3 to 20mm pumice clasts, clast supported, with occasional clasts of spherulitic rhyolite and minor interstitial matrix of sub 2mm pumice fragments, quartz and feldspar crystal fragments, broken spherulites and secondary void filling of quartz, red/brown semi opaque hematite and calcite or sericite.

Pumice clasts make up 75% of this rock, and are partly crushed vesicular pumices with vesiclular textures and whispy terminations visible in ppl, but under cross polarised light are recrystallised to fine grained felsitic texture with some fine grained chlorite and sericite alteration and some calcite patches. Clasts are porphyritic with occasional 1–3mm bipyramidal beta quartz pseudomorphs, often slightly rounded or embayed, about 3%, also 2% euhedral sericite/calcite replaced sodic plagioclase, and 1–2% red-brown biotite.

Sparse matrix is comprised of smaller pumice fragments, spherulitic rhyolite clasts (very similar to F22, GA11C rhyolite) and broken quartz, sodic plagioclase and occasional biotite. Also euheral quartz needles, sericite and calcite as void filling, and many pumice clasts appear rimmed with brown hematite staining (possibly vapour phase alteration).

Vitric Pumice clasts: 75%, Matrix pumice 10%, Matrix Crystal fragments: 3%, Rhyolitic rock fragments: 7%. Secondary quartz, calcite and sericite voidfilling: 5%.

Field Number	Formation:					
WI9 *	Ibáñez tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
276970	4864220	12	1	87		100
Final Rockname						
Rhyolitic Ignimbrite						

Microscopic textures (WI9):

Ignimbrite with large (1–5mm) crystal fragments of quartz and sodic plagioclase, occasional biotite and sparse oxidised andesitoid lithic fragments, with a patchy matrix of partially recrystallised vitroclastic ashy matrix.

Crystal fragments are about 10–12%, 6% large angular and broken beta quartz crystal fragments, rounded and embayed: 4–5% partially sericitised and murky altered subhedral sodic plagioclase, albite or albitised, also angular and broken: and trace to 1% partially chloritised cleavage fragments of green-brown biotite.

Lithic fragments are rare, about 1%, although they may range from 0.54mm. Fragments are angular or subangular silicic tuff rock fragments or pilotaxitic textured andesitic rock fragments with swallowtail plagioclase morphology.

Groundmass is devitrified vitroclastic material, with patchy variation in the degree of destruction of the vitroclastic texture. Some areas have near complete destruction and replacment by uniform felsitic material, with shard textures only present as ghosts in plain polarised light, while other areas have well preserved shard textures only partially replaced by felsitic material. Areas with well preserved shard textures show common fine disseminated hematite, which appears to have retarded the complete replacement of shards and allowed preservation of textures. Also common sericite, and individual shards may have irregular radial or edge perpendicular spherulitic and mosaic recrystallisation textures.

Field Number	Formation:					
WI21 *	Ibáñez tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
272650	4865620					0
Final Rockname						
Rhyolitic Ignimbrite.						

Microscopic textures (WI21):

Quartz: Up to 4mm, euhedral or rounded and embayed bipyramids, often shattered. Also in coarsley recrystallised g/mass and secondary prisms in cavities.

Feldspars: Present, but almost all completely sericitised. Albite or K-spar.

Other minerals: Opaques include leucoxene and hematite. Biotite trace, altered to muscovite and opaque leucoxene along cleavage. Zircon is associated with altered biotites.

Groundmass: Fine grained felsitic texture of devitrified material, glass shard textures pseudomorphed by abundant ?hematite opaques. Sometimes coarse recrystallisation to quartz/feldspar mosaic has taken place.

Lithics: Up to 4mm across in thin section, Altered pumices and fragments of Spherulitic rhyolite.

Field Number	Formation:					
WI23	Ibáñez tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
270330	4863220	22	5	73		100
Final Rockname						
Bedded rhyolitic tuff.						

Microscopic textures (WI23):

Quartz, 0.1 to 3mm, 1–2% max. Euhedral or fractured bipyramids, also as part of devitrified felsitic texture and recrystallised groundmass

Feldspars are sparse, altered and sericitised about 20%, mostly Plagioclase, RI of fast and slow directions below epoxy, so probably Albite. Crystals euhedral, but often shattered. Also trace K-spar: ? V small 2v, Oap parallel to 010 so High sanidine.

Other minerals: Hematite staining in g/mass from ?altered opaques and mafics. Trace Calcite present, usually associated with altered feldspar. Trace muscovite and ?Leucoxene as alteration of Biotite.

Groundmass about 73% of rock, with Felsitic texture to mosaic texture of recrystallised glass shards and and common coarse felsitic textured devitrified pumices, up to 8mm, porphyritic with plagioclase crystals sometimes glomeroporphyritic within pumices, occasional ghost shard textures visible in ppl. Fine grained opaques common, plus sericitised material.

Lithic fragments are about 3–5%, include felsitic Rhyolite, trachytic intermediate rock fragments.

Field Number	Formation:					
WI35	Ibáñez tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
275500	4858500	20	70	10		100
Final Rockname						
Dacitic Lithic Tuff, probably precursor ashfall or surge deposits to the overlying lavas.						

Microscopic textures (WI35):

Massive deposit of lithic and crystal rich tuff, with rock and crystal fragments of dacitoid composition, in a matrix of devitrified felsitic material and finer graiued crystal and lithic fragments. Lithification and alteration, together with the similarity of clast and matrix composition, make estimation of clast/matrix proportions difficult.

Crystal fragments are about 20%, with very sparse quartz, oxidised and chloritised mafics, and common Feldspar, up to 3–4mm, but also make up much of the fine microphenocryst size crystals in the matrix. Crystals are Sodic Plagioclase, partly altered and sericitised, but Albite-carlsbad twinning gives 17,5 about An25%, Oligoclase.

Clasts of dacitic mineralogy (Oligoclase, altered mafics, felsitic-pilotaxitic or intergranular groundmass) are angular, difficult to determine boundaries in thin section, but in hand specimen are about 70% of the rock, leaving about 10% matrix of similar mineralogy (sodic plagioclase, felsitic devitrified material, secondary chlorite, calcite, sericite.) Quartzite xenoliths also occur.

Calcite and chlorite occur as void filling and cement.

Field Number	Formation:					
WI39A	Ibáñez tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
273941	4856130					0
Final Rockuame						
Altered dacitic lithic tuff/breccia.						

Microscopic textures (WI39A):

Clastic rock composed of medium to coarse sand-size rock and crystal fragments. Fragments are devitrified felsitic material, with small altered feldspar crystals. Crystal fragments are sericitised feldspar, probably albite or oligoclase, from twins in some remnant crystals.

Rock fragments are angular to sub-angular, and have been cemented by ?devitrification/zeolitisation process, which has deposited a clear rim of felsitic material over the clasts. Iron staining is common, and mauy voids are filled with goethite, celadonite or chlorite.

Feldspars are sericitised or replaced with calcite.

Poor bedding is defined by slight imbrication of clasts. Occasional plate of tridymite occurs.

Field Number	Formation:					
WI56 *	Ibáñez tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
270970	4865710					0
Final Rockname						
Rhyolitic Ignimbrite.						

Microscopic textures (WI56):

Well preserved rhyolitic ignimbrite with common quartz, sericitised feldspar and biotite crystal fragments in a devitrified felsitic groundmass of ashy material and pumice fiamme with spherulitic texture and sericite alteration patches.

Quartz is about 10%, up to 2mm subhedral bipyramids, embayed, rounded and fractured.

Feldspars are 15–20%, mainly sericitised sodic plagioclase, subhedral and fractured, and embayed with patchy fine grained sericite invading along cleavage planes or by zones. Some sodic plagioclase appears to have partial alteration to K-spar, occurring as low RI patches within albite twinned crystals.

Biotite is green-brown, chloritised or altered to chlorite, reddish brown hematite and muscovite, as euhedral booklets or cleavage fragments up to 1mm. About 1%.

Rock fragments are sparse, less than 1%, generally angular fragments of oxidised rhyolitic tuff.

Matrix is 65–70% of rock, brownish stained with fine disseminated iron oxides in ppl, and showing well preserved vitroclastic textures with flattened glass shards and wrap around textures and partially spherulitic devitrified fiamme with network or vein sericite replacement.

Field Number	Formation:					
WI72 *	Ibáñez tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
269539	4868620	5	12	83		100
Final Rockname						
Rhyolitic Ignimbrite.						

Microscopic textures (WI72):

Well recrystallised tuff, with groundmass of fine grained felsitic material partially recrystallised to mosaic quartz-feldspar, and showing only occasional ghost remnants of vitroclastic textures.

Crystal fragments are about 5%, mainly small <2mm sub angular to rounded fragments of sodic plagioclase, usually albite, with common sericite and murky alteration. Trace angular quartz fragments and biotite.

Rock ragments are also sparse, about 5–8%, fine grained 0.4–3mm rounded fragments of tuff, tuffaceous sediments, pilotaxitic andesitic rock fragments, and occasional fragments of microgranodiorite. Some are altered and oxidised, with opaque hematite and yellow or green chlorite.

Matrix is fine grained felsitic material after vitroclastic textured ashy matrix, although most vitroclastic texture now gone. Patchy recrystallisation to quartz-felspar mosaic occurs throughout. Some faintly visible fiamme also remain. Fine sericitic muscovite and chlorite occur as replacement and alteration of groundmass.

Field Number	Formation:					
WI93B	Ibáñez tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
272390	4864430					0
Final Rockname						
Moderately to poorly sorted and graded tuffaceous coarse sandstone.						

Microscopic textures (WI93B):

Quartz: Common, 15–20% crystals 0.2–3mm, embayed or fractured subhedral bipyramids, with visible dust rims and overgrowths. Also present in groundmass as anhedral mosaic with feldspar in felsitic alteration of pumice, or as euhedral secondary crystals in calcite.

K-spar: ?trace. Small 2v, -ve, altered, untwinned feldspars. ?Sanidine.

Plagioclase: Plagioclase ML: 10, 6.5,11.5, 14, 3.5, 4.5, 6. so Albite or Oligoclase.

Other minerals: 50% plus Calcite — secondary cement and alteration product. Biotite, Trace, altered to opaques, probably leucoxene exolved along cleavage, and muscovite, still with the same optical orientation as the original biotite. Leucoxene as alteration product of biotite. Muscovite also as sericitic fine alteration product in pumice, with calcite and felsitic Quartz/felds.

Groundmass: Calcite cement, perhaps replacing original material, plus felsitic devitrified ?ash/glass.

Lithics: Felsitic rhyolite fragments, cherty quartz fragments. Common altered pumices, either devitrified and felsitic, or mostly replaced by calcite.

Field Number	Formation:					
PI49A	Ibáñez tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
269225	4872569	30	25	45		100
Final Rockname						
Massive rhyolitic Tuff.						

Microscopic textures (PI49A):

Poorly sorted, angular Crystals, rock fragments and pumices are matrix supported in a brownish devitrified felsitic groundmass.

Quartz: 1-5%, up to 1.5mm. Anhedral fractured or subhedral rounded and embayed crystals.

Feldspars: 25%, 0.2 to 3mm altered Sodic Plagioclase and K-spar. Sanidine, Fractured 0.2–3mm crystals, small 2v, not as strongly altered as plag. Plagioclase is altered crystals, often sericitised or replaced by calcite. RI indicates Albite or very sodic Oligoclase.

Other minerals: anhedral patches of calcite, and occasional euhedral carbonate rhombs as replacement of lithics and growing in groundmass, possibly dolomite or siderite. White reflective opaques probably leucoxene. Common dark green chlorite patches, fine platy masses. Infilling vesicles and alt'n of ?biotite.

Groundmass: 35%. Murky brownish in ppl, Felsitic textured in cpl, probably devitrified ash. Common plates of fine sericitic muscovite, patches of chlorite and leucoxene as dominant opaque. Trace vitroclastic texture, but mostly altered or devitrified beyond recognition.

Pumices are common, 10%, devitrified, relatively undeformed, with visible, rounded vesicles, often filled with bright chlorite. Devitrification has altered the glass to fine felsitic material. Some pumices are stretched and flattened.

Rock fragments are up to 25%, 0.25–5mm, and most are pilotaxitic sodic plagioclase rich dacitic volcanic fragments, some felsitic and poikilomosaic recrystallised rhyolitic volcanic fragments, cherty sediments and dolomite bearing muddy fine grained sediment.

Field Number	Formation:					
L5β *	Ibáñez tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
281170	4859500	22	4	74		100
Final Rockname						
Devitrified poorly welded upper zones of a rhyolitic ignimbrite, crystal rich, pumice poor.						

Microscopic textures (L5β):

Ignimbrite, with crystals of quartz, plagioclase, biotite, perhaps k-spar, and lithic fragments, in a matrix of devitrified ash and finely broken crystal fragments, with secondary calcite, chlorite, etc.

Quartz is broken fragments of embayed beta quartz bipyramids, some up to 3mm, about 10–15%, but also present as recrystallisation of devitrified gronndmass material.

Plagioclase is about 5%, present as broken subhedral crystals, 0.2–1mm, often altered with calcite replacement of cores or even entire crystals. RI measurement suggests sodic oligoclase, as greater than fast quartz, but less thau/equal slow quartz.

Biotite is euhedral cleavage sections/booklets, 0.2–0.8mm, brown to dark brown pleochroic, fresh, with no alteration to chlorite, but sometimes with inclusions of apatite and trace zircon. 1–2%.

K-spar trace? may occur as sparse broken subhedral crystals, with very low RI, below epoxy, and without albite twins. Intermediate 2v, 60-ish to 40-ish, but positive? May just be sections of albite not showing twins.

Groundmass is about 74%, devitrified and recrystallised felsitic quartz/feldspar sometimes replacing and psendomorphing original glass shard textures, together with patches of calcite and sericite. Quartz mosaic material has replaced most shard pseudomorphs. Fine grained opaque magnetite and hematite occur, and traces of green chlorite or fine grained amphibole. No pumices or fiamme texture.

Lithic fragments are small, 0.1–4mm fragments of oxidised andesitoids and spherulitic rhyolites, etc. 4%.

Field Number	Formation:					
F57A *	Ibáñez tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
280710	4867530	4	5	91		100
Final Rockname						
Rhyolitic pumice flow/vitric tuff.						

Microscopic textures (F57A):

Pyroclastic rock with occasional quartz and rock fragments in a well preserved matrix with glass shard textnres still visible, partly recrystallised to felsitic texture.

Quartz crystal fragments are sparse, broken bipyramids, about 1mm across, less than 1%, and feldspars are slightly more common, as broken, murky and altered subhedral crystals, albite twinned, look to be altered sodic plagioclase, probably albite. Feldspars are also small, about 0.5mm, 2–3%.

Rock fragments are about 5%, oxidised, altered intermediate and felsitic textnred silicic volcanics. Range from sub 1mm up to 10mm in hand specimen.

Matrix is about 90% felsitic textnred recrystallised ash, with shard textures visible in ppl, but recrystallised with slightly larger grainsize in cpl, and only faintly visible. Pumices, are about 10% of groundmass, with felsitic recrystallisation or replacment by calcite and sericite. Pumices have whispy ends, but are moderately flattened.

Field Number	Formation:					
GA11A	Ibáñez tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
288426	4871485	16	5	79		100
Final Rockname						
Rhyolitic tuff or ignimbrite.						

Microscopic textures (GA11A):

Altered tuff, with crystal fragments of quartz, plagioclase, k-spar and biotite, with lithic fragments of intermediate to rhyolitic volcanic rocks, in a matrix of devitrified fine grained ashy material with patches of pumice altered to whispy networks of sericitic muscovite. This rock may have undergone a thermal event from the intrusion of the adjacent Cerro Cabeza Blanca rhyolite dome.

Quartz crystal fragments are sparse, 5%, less than 1.5mm, subhedral broken bipyramids.

Feldspars are also small and spase, about 10%, with about 8% Plagioclase as partly sericitised or calcite replaced crystals. C-Albite gives: 10, 15, About Oligoclase, but some crystals show irregular patchy structure reminiscent of coarse perthite, with high albite extinction in some places and low in others. Other feldspar crystals, untwinned or carlsbad twinned, are murky and altered, and have lower 2v, 40–60ish, High Sanidine? Oap appears parallel to 010, so High sanidine, about 2%.

Biotite occurs as fresh, euhedral booklets or cleavage fragments, up to .5mm, 1%

Matrix/groundmass is about 75–79% of the rock with occasional vague remnants of shard textures, but is generally colourless or slightly green streaked material in ppl, and in cpl shows felsitic texture with occasional streaks of secondary sericitic muscovite and remnants of glass shards as patches of quartz-feldspar mosaic material. Muscovite occurs as fine networks and fibrous replacement of pumice material and groundmass, slightly greenish in ppl. Pumice fragments are about 5-10%, generally devitrified and sericitised, some have messy spherulitic texture or fine quartz/feldspar recrystallised mosaic texture.

Lithic fragments are angular or snb angular, up to 5mm, about 5%, reddish or greenish oxidised tuff, andesitoid lava or rhyolitic volcanic rocks. Some chlorite replaces mafics in andesitoid lithics.

Field Number	Formation:					
PI52	Ibáñez tuff/Ig (Altered)					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
270230	4873945	25	5	70		100
Final Rockname						
Altered rhyolitic Tuff.						

Microscopic textures (PI52):

Quartz, Feldspar and pumice fragments matrix supported in a fine devitrified felsitic groundmass. Common Fe-oxide staining and calcite patches.

Quartz: 3–5% 0.2–3mm. Generally subhedral, very strongly embayed in some crystals, but not commonly rounded. Often fractured.

Feldspars: 20%, 0.2–2mm. Strongly altered, often replaced by calcite, opaques. Subhedral or fractured Sodic Plagioclase and K-Spar. Sometimes partially replaced by Hematite and calcite. Plagioclase is Albite, RI just below glue, often replaced partially by calcite.

Other minerals: Common calcite, as alteration of Plagioclase and as patches within g/mass. Dominant opaque is ?hematite, with big oxide stain patches around grains of it.

Groundmass: 60% Densely matted brownish material, occasional with very fine grained opaques, Felsitic in cpl, possibly still partly glassy, as almost black in cpl. Trace glass shard ghosts.

Pumices common, 10%, up to 10mm long, devitrified with common quartz mosaic, or alteration to calcite. Well flattened and typical fiamme whisp ends occur.

Occasional (3–5%) angular lithics of felsitic and poikilomosaic recrystallised rhyolite.

Field Number	Formation:					
PI79B *	Ibáñez tuff/Ig (Altered)					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
275220	4873570					0
Final Rockname						
Purple/mauve poorly sorted fine ash to small lapilli size crystals and lithics in fine ashy devitrified matrix, Rhyolitic Tuff.						

Microscopic textures (PI79B):

Baked/devitrified iron stained tuff with quartz/feldspar/lithics in a matrix of devitrified glass shards, and secondary iron oxides as opaque seams, probably the result of thermal effects.

Quartz 1–3%, up to 2mm. Rounded and embayed or fractured crystals.

Feldspars: 10–15%, subhedral and euhedral crystals up to 2mm. ?Mostly sodic plagioclase, RI fast and slow are both below glue, ML is inconclusive, but small angle, probably albite. 2v is large, close to 90. Some sericitic alteration.

Other minerals: Trace Epidote as subhedral crystals in voids and groundmass. Calcite present as void filling, and as alteration of pumice clasts and feldspars. Trace amphibole, possibly xenolithic.

Groundmass: Fine grained felsitic material, with ghost shard texture sometimes visible in ppl. Devitrified, ashy material, speckled with fine ?hematite opaques, also seams of calcite and oxide stains. Pumices up to 5–6mm, ragged, flattened and devitrified to coarser felsitic texture than the groundmass. Often altered/replaced by calcite.

Lithics: Lithics include fragments of glass-rich welded tuff, minor felsitic rhyolitoids.

Field Number	Formation:					
PI78	Ibáñez tuff/Ig (Altered)					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
274950	4873620					0
Final Rockname						
Altered rhyolitic tuff.						

Microscopic textures (PI78):

Well developed vitroclastic texture, with flattened shards and wrap around textures. Pervasive hematite opaques, perhaps from baking, and large lithic fragments.

Quartz: 3–5% in matrix, but 10–15% in large lithic block. Rounded, Anhedral and embayed or fractured crystals,

Feldspars: Very altered, K-spar and Sodic Plagioclase.

Biotite: Trace, altered crystals present in lithics

Muscovite: Trace, in devitrified lithic, and in biotite altered to hematite and muscovite.

Chlorite: Trace, as patches in groundmass, and alteration of mafic minerals.

Other minerals: Dominant opaques are hematite (Ubiquitous, red under reflected light), with ?alteration to Goethite/limonite and Leucoxene, in small white patches.

Groundmass: 55–60 or 70%. Dominated by vitric material, but with dense alteration/deposition by secondary hematite staining and cement. Some hematite almost forms seams, like unto dissolution seams. Glass shard textures well preserved, but shards themselves devitrified. Some wrap around textures of shards or pumice frags around crystals and lithics.

Lithics: Lithics include pebbles and cobbles of crystal rich tuff, similar to the tuff matrix but fines depleted and clast supported. Smaller lithics include andesitoids dacitoids, felsitic rhyolitoids, fragments of microlitic obsidian and cherty devitrified material. Pumices are blocky, whispy at edges and devitrified.

Field Number	Formation:					
F54	Ibáñez tuff/Ig (Altered)					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
280400	4868450	20	5	75		100
Final Rockname						
Devitrified and recrystallised dacitic tuff.						

Microscopic textures (F54):
Altered dacitic tuff or Ignimbrite, with felsitic groundmass recrystallising to quartz/feldspar mosaic, and sodic plagioclase feldspar phenocrysts altered to clay or sericitic material, trace of small rounded quartz crystals. Common calcite patches, and pumice fiamme are replaced by calcite or by felsitic material of slightly different grainsize to groundmass. Lithic fragments are sparse, rhyolitic rock fragments, with slight overgrown quartz rim from recrystallising groundmass. Maybe some siderite along with calcite. Feldspars appear to have been sodic plagioclase, while quartz crystal fragments are rare and small, so perhaps closer to dacite than rhyolitic. Very faint shard or pumice whisp shapes are preserved in different grain sizes of felsitic groundmass and recrystallised quartz mosaic. Presume mosaic recrystallisation driven by heat from nearby intrusive bodies.

About 20% crystal fragments, (Sericitised sodic plagioclase, rare quartz), 4–5% rhyolitic lithic fragments, 75% devitrified felsitic to mosaic quartz replacing ashy matrix. Also secondary calcite, sericite.

Field Number	Formation:					
WI19	Ibáñez tuff/Ig (Altered)					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
273190	4865740	22	5	73		100
Final Rockname						
Rhyolitic Ignimbrite.						

Microscopic textures (WI19):
Phenocrysts and lithic fragments are matrix supported in a fine grained felsitic material with traces of shard texture and pumice fragments.

Quartz: 0.1–3mm, 5–10% Embayed and bipyramidal euhedral crystals, often shattered.

Feldspars crystal fragments are about 10–12%: 0.1–1mm, Carlsbad twinned low RI k-feldspar, some albite. K-spar has Low RI, low to moderate 2v,positive and negative — Sanidine.

Other minerals: Trace zircon. Rounded amorphous clots of opaque in the groundmass are white under reflected light, and may be leucoxene. — is the dominant opaque. Also dark red-brown semi-opaqne hematite common, as alteration of ?magnetite/mafics. Muscovite common as recrystallised and coarsened sericitic altn. of feldspars and pumices.

Groundmass: About 70% of rock. Recrystallised/devitrified felsitic material, little or no remnant vitroclastic texture, but some sericitised fiamme present. Pumice fragments are either sericitised or devitrified, and often contain euhedral phenocrysts of quartz or feldspar.

Lithics are about 2–5%, Quartzite, trace other meta-quartzose rocks. Felsitic rhyolitoids common. Up to 2mm–3mm.

Field Number	Formation:					
CP27A	Ibáñez tuff/Ig (Altered)					
Utm East	Utm North	CF:	RF:	V:		Snbtotal:
277341	4869075	6	20	74		100
Final Rockname						
Altered small pumice lapilli tuff.						

Microscopic textures (CP27A):
Tuff with well developed fiamme texture, but poorly preserved vitroclastic texture, quartz crystal fragments 0.1–3mm, common calcite, and devitrifed groundmass of quartz/calcite/sericite/clays, as well as chlorite and opaque iron oxides.

Quartz crystal fragments are unaltered, rounded and fragmental beta quartz up to 2mm, but most less than 1mm, only about 1%.

Feldspar crystal fragments are sericitised or entirely replaced by calcite, were broken subhedral crystals, remnants are low RI and low 2v, perhaps Sanidine, but difficult to tell with alteration. About 5% max, up to 2mm.

Lithic fragments are 15–20%, angular to rounded fragments of oxidised pilotaxitic and vesicnlar andesitoids. 1–6m I in section, up to 10cm in hand specimen.

Remainder of rock is altered and devitrified pumice and ashy groundmass, with vitric material in well recrystallised to felsitic texture and with anastomosing networks of fibrous sericite and patches of chlorite and calcite. About 74% of rock.

Field Number	Formation:					
CP43A	Ibáñez tuff/Ig (Altered)					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
277359	4869675	13	5	82		100
Final Rockname						
Silicified and recrystallised rhyolitic tuff.						

Microscopic textures (CP43A):

Quartz is common as recrystallisation material in groundmass. Crystal fragments are broken and embayed birpyramids, up to 4mm, 2–3%.

Feldspars are about 8%, as altered fragmental crystals, replaced by calcite, sericite, etc. Altered plagioclase has remnant albite and carlsbad twinning, RI fast and slow well below expoxy, so Albite.

Trace to 1% Sanidine K-spar may be present, also as replacement of plagioclase by low t K-spar along fractures, veins, or as rims around crystals which may be primary rimming of zoned plagioclase by late stage k-spar before eruption.

Biotite 1%-trace, 0.4–0.5mm cleavage flakes and booklets, altered to Muscovite, opaque iron oxides and leucoxene.

Opaque minerals are mainly reddish brown hematite, and some white leucoxene, trace.

Lithics up to 5mm, 2–5%, range from fragments of other ignimbrites, rhyolitoids, pilotaxitic andesitoids. Many oxidised and strongly stained or replaced with hematite and Fe oxides.

Groundmass is about 82% brown in ppl, and has faintly visible glass shard textures. In CPL, it is a uniform felsitic texture, although larger shards have devitrified to fine mozaic and cherty-textured quartz and feldspar. Recrystallisation has coarsened up some patches of this mosaic material, and quartz overgrowths have occurred on some quartz crystal fragments. Common patches of secondary calcite as void filling and replacment.

Field Number	Formation:					
F2A *	Ibáñez tuff/Ig (Altered)					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
288123	4865027	25	35	40		100
Final Rockname						
Altered Rhyolitic Ignimbrite.						

Microscopic textures (F2A):

Altered lithic tuff or iguimbrite, with crystal phase of broken beta quartz, altered plagioclase and lithic fragments, matrix supported by recrystallised felsitic groundmass with much replacement by calcite, sericitic muscovite and chlorite.

Quartz is rounded and broken beta quartz pseudomorphs, relatively unaltered apart from slight secondary overgrowths of mosaic quartz ou some grains. 3–5%, up to 2mm.

Feldspars are about 15–20%, up to 3–4mm. Plagioclase is subhedral to euhedral broken crystals, carlsbad and albite twinned, with clay and sericitic alteration and replacement by calcite. Section Tc and RI fast and slow below epoxy indicates Albite or albitised. K-spar is present as occasional carlsbad twinned crystal fragments, with 2v 60-70 and oap parallel 010, and RI well below adjacent sericitic mica.

Groundmass is about 40% of rock, and has remnant patches of felsitic texture, recrystallised from ashy material, and very faint glass shard textures are present in places, however most of the felsitic material has been replaced by chaotic fibrous and anastomosing platy sericite, green chlorite and possibly celadonite, as well as patches of calcite. Chlorites are length slow types, with anomalous blue interference colours (Pycnochlorite?)

Fiamme are also replaced with sericite, calcite, chlorite, but vesicle textures are still visible in some fiamme.

Lithic fragments are: Rhyolitoid lava aud tuff, often recrystallised or altered. Some mosaic quartz recrystallisation. Also fragments of audesitoid, with hematite and other opaque oxidation products. About 35%.

Field Number	Formation:					
PI10	Ibáñez tuff/Ig (Altered)					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
283424	4859525					0
Final Rockname						
Devitrified and altered block & ash tuff.						

Microscopic textures (PI10):

Altered tuff, with patches of calcite and goethite alteration, common crystal fragments of sodic plagioclase, rare quartz, and lithic fragments of pilotaxitic dacitoids with sodic plagioclase phenocrysts and poikilomosaic quartz rich groundmass. Groundmass of tuff is felstic material with fine grained platy chlorite and sericite alteration with patches of calcite and quartz mosaic recrystallisation. Some altered pumices, mainly felsitic material with large calcite patches, porphyritic with altered sodic plagioclase.

Field Number	Formation:					
WI118A	Ibáñez tuff/Ig (Altered)					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
269310	4864530	38	20	42		100
Final Rockname						
Rhyolitic lithic tuff.						

Microscopic textures (WI118A):

Altered tuff, matrix poor and crystal/lithic/pumice rich. Thin section is cut a little thick. Secondary calcite, chlorite and sericite are common as alteration of feldspars, groundmass, pumices and also as void filling.

Crystal fragments are altered feldspars and quartz, both subhedral and fractured crystals.

Quartz is about 8%, broken subhedral and rounded bipyramid fragments.

Feldspars are 25–30%, 0.5mm or less up to 3mm, (or 5–10mm glomeroporphyritic clusters in pumices), subhedral and broken, with pervasive alteration to brownish clayey material or patchy sericite and calcite. Some remnants show albite twinning, so mostly sodic plagioclase.

Lithics are about 20%, mainly pilotaxitic and felsitic textured 1–3mm fragments of brownish hematite rich oxidised dacitoid volcanic fragments, and also occasional fragments of quartzite.

Pumices are common, about 25%, up to 20mm in hand specimen, porphyritic with euhedral altered sodic plagioclase and vitric matrix recrystallised to felsitic or poikilomosaic quartz or replaced by calcite.

Matrix is fine grained felsitic material with very sparse ghost shard textures in ppl, about 17% of rock.

Field Number	Formation:					
CP85	Ibáñez tuff/Ig (Altered)					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
279140	4869990	6	35	59		100
Final Rockname						
Altered rhyolitic lithic tuff.						

Microscopic textures (CP85):

Felsitic crystal poor lithic tuff, with sparse crystals of fragmental feldspar and quartz in a felsitic devitrified matrix with large (up to 10mm) angular lithic fragments.

Quartz is broken small fragments, 0.2–0.8mm, sometimes rounded and embayed. 1%.

Feldspar crystals are euhedral to subhedral fragments, 0.5–1mm, partly sericitised, with albite and carlsbad twins, 2v moderate to large (60-80) Oap — 010. Probably Albite, although some may be k-spar. About 5%. Also occasional Sanidine crystal.

Lithic fragments are large, from 1mm to 10mm, angular, matrix supported clasts of spherulitic and felsitic rhyolite, and some fragments of dacitic material with poiklomosaic quartz and pilotaxitic feldspar microphenocrysts. Some sericitic alteration of feldspars and common poikilomosaic quartz textures are present in groundmass of clasts. About 35% of rock.

Groundmass is fine grained felsitic devitrified ashy material, with faint shard and fiamme textures visible in ppl, and some replacement of fiamme with muscovite. Shard textures in cpl are visible as faint variations of grainsize of felsitic texture. About 55–59% of rock.

Additional secondary alteration: Opaques are altered to brownish hematite/goethite, and sometimes leucoxene. Patches of platy muscovite occur where sericitic alteration of groundmass or feldspars has recrystallised.

Field Number	Formation:					
CP80	Ibáñez tuff/Ig (Altered)					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
278640	4868840	18	15	67		100
Final Rockname						
Altered and devitrified rhyolitic tuff.						

Microscopic textures (CP80):

Pyroclastic rock with broken subhedral sodic feldspars and quartz, chloritised biotites, rock fragments, sericitised pumices, in felsitic or mosaic quartz/feldspar recrystallised groundmass.

Quartz is broken 0.5–1mm fragments of rounded and embayed igneous quartz, about 2–5%.

Feldpars are about 10%, mainly sodic plagioclase, 2v high, +ve 80 ish, often sericitised, not enough twinning for accurate ML. Given signs of thermal effect on this rock, probably Low Albite.

Muscovite (2%.) occurs as fine fibrous sericitic alteration of feldspars and pumice fiamme, also within groundmass, but also as larger subhedral slightly pleochroic green grains, platy and up to 0.2mm, randomly orientated in decussate texture, sometimes associated with chlorite, may be alteration of biotite.

Biotite occurs as sparse pale brown pleochroic grains, euhedral or cleavage booklets, up to 0.5mm, trace-1%

Rock fragments are up to 2–5mm, about 15%, silicic volcanics, oxidised and recrystallised.

Groundmass is 67% of rock, fine grained felsitic textured material, sometimes partly recrystallised to mosaic quartz/feldspar. Occasional chlorite, calcite, patches of sericite, 1–3% opaques. Chlorite occurs as granular or platy patches in groundmass, also as blocky pseudomorphs of mafic mineral.

Also trace pleochroic dark blue-light brown mineral, uniaxial negative, so probably Tourmaline, perhaps Schorl variety. Possibly riebeckite but uniaxial negative figure makes this very unlikely. Birefringence about .020, so perhaps from Elbaite-Schorl series, probably Authigenic.

Field Number	Formation:					
PI99B	Ibáñez tuff/Ig (Hornfelsed)					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
276400	4872750					0
Final Rockname						
Albite epidote hornfels (Rhyolitic lithic tuff.)						

Microscopic textures (PI99B):

Hornfelsed lithic tuff with common radial and granular epidote porphyroblast clusters.

Lithics are coarse ash to small lapilli size fragments of pilotaxitic andesitoid and dacitoid, altered, and occasional poikilomosaic recrystallised rhyolitoid.

Matrix is felsitic textured recrystallised ashy material with crystal fragments and ash size lithic fragments.

Most clasts are partly recrystallised to poikilomosaic quartz around original pilotaxitic feldspar, and are spotted with fine granular patches of epidote. Chlorite is common as alteration and void filling with some epidote and euhedral quartz needles. Chlorite is radial platy clusters with deep blue interference colours.

Lithics about 35–40%, voids with epidote/chlorite/quartz filling about 15–20%, altered feldspar and quartz crystal fragments about 10%, devitrified ashy matrix about 30%.

Field Number	Formation:					
PI100	Ibáñez tuff/Ig (Hornfelsed)					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
276132	4872833					0
Final Rockname						
Albite epidote hornfels. (Rhyolitic ignimbrite.)						

Microscopic textures (PI100):

Fine grained felsitic groundmass with clots of pumice and feldspars altered to epidote/chlorite/sericite. Altered pumice and streaks of ?Fe oxide in groundmass define poor eutaxitic texture.

Quartz: Sparse, Less than 1%, anhedral fractured grains up to 1mm. Also present in devitrified groundmass material.

Both sodic plagioclase and K-spar present, but often sericitised or partially replaced by epidote. K Feldspar has RI strongly below glue, 2v small to moderate, probably anorthoclase or sanidine, but now altered.

Plagioclase RI both fast and slow directions is below glue, so probably Albite.

Other minerals: Calcite, as void filling, and alteration of ?sodic plagioclase. Epidote, alteration of Feldspars and pumices, and generally as clots/spots of thermal effect. Uniaxial negative ?zeolite in some altered intermediate volcanic lithics. Leucoxene occurs as dominant opaque mineral. Some hematite patches/staining. Chlorite present in groundmass, as alteration of ?fiamme or ?biotite.

Groundmass: Brownish fine felsitic material, occasionally with faint glass shard textures. Devitrified, with shards altered to ?quartz/felds/sericite mix, often destroying any shard textures. Occasional patches of fine epidote, and chlorite. Leucoxene is common as alteration of opaques, as is some brown hematite oxide staining. Pumices, 5% occur as felsitic devitrified lenses up to 8–10mm long, often altered to granular euhedral epidote and chlorite/sericite mix.

Lithics: Lithic fragments include andesitoids, rhyolitoids, spherulitic rhyolitoids, dacitoids. All, particularly basic ones, are altered, with common granular or radial patches of epidote.

Field Number	Formation:					
CF25B	Ibáñez tuff/Ig (Hornfelsed)					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
272151	4878035					0
Final Rockname						
Hornblende hornfels (tuff or tuffaceous medium sandstone).						

Microscopic textures (CF25B):

Fine grained rock with a cherty texture, with occasional fragmental crystals of volcanic quartz in a fine felsitic to cherty textured groundmass of quartz, sericite and perhaps feldspar. Veins of quartz occur, as do large patches of sericite. Rare Andalusite.

Groundmass is fine grained cherty quartz/feldspar mosaic, with coarser recrystallisation near quartz veins. Ghost impressions of lithic fragments and glass shards occur, as do remnant lithics. Some sericite coarsens up to fine muscovite. Trace amounts of green chlorite and blue green ?hornblende occur.

Andalusite occurs in a single complex porphyroblast composed of several crystals in a rough radial pattern, associated with a cherty to mosaic quartz recrystallisation patch and coarsened and recrystallised sericitic muscovite. High relief, straight extinction, fast along, low birefringence.

Quartz is common throughout the groundmass as recrystallised felsitic to cherty material with feldspar, but also as remnant fragmental volcanic crystals with overgrowths of cherty or mosaic quartz. Some appears to be broken ignimbritic or pyroclastic derived, while other grains are still within mosaic-quartz recrystallised rhyolitoids.

Lithics identifiable are angular fragments of rhyolite, Quartzite, and cherty angular fragments that may be recrystallised fine crystal poor tuff. Max size about 5mm. Larger sericitic patches may be remnants of pumice.

Looks like a hornblende-Hornfelse facies altered tuff or tuffaceous sandstone from the Ibáñez formation.

Field Number	Formation:					
WI38A	Ibáñez tuff/Ig (Hornfelsed)					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
274840	4857120	15	20	65		100
Final Rockname						
Hornblende Hornfels. (Rhyolitic Tuff.)						

Microscopic textures (WI38A):

Well recrystallised and probably hornfelsed silicic tuff. At first glance looks like Phenocrysts of embayed bipyramidal quartz and sericitised sodic plagioclase occur in a well recrystallised fine grained mosaic quartz matrix, with patches of coarse recrystallisation to well developed granoblastic quartz. However, in plain polarised light faint pyroclastic textures show up, and the rock can be seen to be lithic and crystal fragments held in a well recrystallised ashy matrix. This rock also contains xenoliths of well recrystallised granoblastic quartzite.

About 5% quartz, 10% Sericitised sodic plagioclase, 15-20% rock fragments, 65% quartz mosaic recrystallised ashy matrix.

Secondary alteration includes calcite, coarsening of the quartz mosaic recrystallisation in the groundmass, growth of some green amphibole porphyroblasts, probably tremolitic.

Opaques are uniformly altered to leucoxene and hematite. Probably a block caught up in the WI47 intrusive.

Field Number	Formation:					
PI17A	Ibáñez tuff/Ig (Hornfelsed)					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
274225	4870845					0
Final Rockname						
Albite-epidote hornfels. (Rhyolitic lithic tuff.)						

Microscopic textures (PI17A):

Rock is a baked and contact metamorphosed lithic tuff, with angular clasts of andesitic, dacitic and rhyolitic material held in a matrix of altered, opaque hematite stained altered ash and rock fragments. Glassy material and feldspars are sericitised or saussuritised to epidote/sericite/albite. Matrix has crystals of broken quartz, saussuritised plag, ?biotite (now altered to muscovite and opaques).

Pyroclasts are less altered than the matrix, and consist of partly recrystallised felsitic rhyolitic and dacitic material, and pilotaxitic fragments of andesitic rock. In thin section these are up to 5mm, but in outcrop the range included large blocks and bombs.

Alteration includes oxidisation and addition to matrix of opaque or dark red hematite cement, sericitisation of glassy material and feldspars, saussuritisation of the same, also growth of epidote throughout the matrix, and quartz mosaic style recrystallisation of some of the more silicic clasts.

Field Number	Formation:					
CP55Dδ	Ibáñez tuff/Ig (Hornfelsed)					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
276517	4871529	20	25	55		100
Final Rockname						
Albite epidote hornfels (Rhyolitic tuff/pumice flow.)						

Microscopic textures (CP55Dδ):

Rhyolitic tuff with recrystallised felsitic textured matrix, common rounded, embayed or fractured quartz bipyramids, with feldspars and fiamme replaced by green chlorite and granular yellow-green epidote, and some sericite. Other crystal fragments are occasional flakes of altered biotite (now pseudomorphed by muscovite with reddish hematite and white leucoxene exsolved along cleavage planes).

Quartz is subhedral rounded and embayed or fractured bipyramids, from 0.3 to 3mm, about 14%.

Feldspars are remnant only, replaced by granular epidote, sericite. Crystals were up to 2mm, subhedral and fractured. From remnant fragments with albite twins and high 2v, probably High Albite sodic plagioclase before alteration. About 5%.

Biotite is present, 0.5–2mm, 1%, as bent and altered cleavage fragments and flakes, altered to opaque leucoxene and muscovite or chlorite.

Lithic fragments are common, 0.2 to 5–6mm, angular and rounded, mainly porphyritic andesitic to dacitic rock fragments, but also fragments of poikilomosaic recrystallised rhyolite, and rhyolitic tuff and ignimbrite fragments, and some rounded fragments of quartzite. Lithics are about 20–25% of the rock.

Groundmass is partly recrystallised felstic material, brown in ppl, with fine grained opaques and traces of glass shard textures and whispy altered pumice fiamme. Fiamme and groundmass show common secondary sericitic and chlorite mica patches or network replacement of felsitic material and fiamme. Some larger fiamme are replaced by large granular patches of epidote. Fine grained sericitic muscovite and chlorite show slight bedding parallel shape preferred orientation. About 55% of rock.

Field Number	Formation:					
CP49A	Ibáñez tuff/Ig (Hornfelsed)					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
277510	4870427	31	15	54		100
Final Rockname						
Albite-Epidote Hornfels. (rhyolitic tuff.)						

Microscopic textures (CP49A):

Rhyolitic tuff with crystal fragments of quartz, feldspar and biotite in a matrix of devitrified felsitic ash with relic shard textures, occasional lithic fragments of volcanic rocks and vitric tuff with well preserved shard textures, and incipiently hornfelsed, with patches of granular epidote, radial chlorite sprays and anastomosing fibrous sericitic mica common in the matrix felsitic material.

Quartz is common large 1–3mm subhedral fractured, rounded and embayed crystals, about 15%.

Feldspar crystals are euhedral to subhedral fractured crystals with patchy alteration to sericte, calcite, chlorite. Some sodic plagioclase has exsolved patches of k-feldspar. Albite-carlsbad twinned crystals have low Rl and low extinction angles, high 2v (80), Albite or albitised (Note growth of epidote patches and sericite within crystals.) Some carlsbad only twinned crystals have Rl fast and slow well below epoxy and Oap // 010, so possibly High Sanidine. About 12% Albite, 3% K-spar.

Biotite occurs as altered bent cleavage fragments, 0.5–1mm, altered to white leucoxene and muscovite. Trace to 1%.

Lithic fragments are oxidised pilotaxitic andestic rock fragments, poikilomosaic devitrified rhyolitic rock fragments and rhyolitic vitric tuff fragments, about 15%, up to 10mm.

Matrix is devitrified felsitic material, with patches of altered pumice, now chlorite/sericite/epidote, and clots of sericite or chlorite common as replacment of felsitic material. Calcite and quartz occur as void fillings. About 54% of rock.

Field Number	Formation:					
PI19	Ibáñez tuff/Ig (Hornfelsed)					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
274300	4871325	15	5	80		100
Final Rockname						
Albite-Epidote hornfels (Rhyolitic tuff).						

Microscopic textures (PI19):

Incipiently metamorphosed tuff, with felsitic groundmass spotted with mosaic quartz recrysallisation and fine granular yellow epidote patches.

Quartz: Sub 0.5 to 2mm, 1–5% Euhedral, embayed.

Feldspars about 10%, anhedral to subhedral broken crystals, .4–2mm. 8%: Plagioclase ML: 13, 4, 8.5, 14.5, 15, Rl below Medium so Albite or albitised. 2%: Sanidine, Small 2v, almost ps-uniaxial, Carlsbad twinned, very low RI.

Lithics: Oxidised lithics of pilotaxitic volcanic rocks, vitroclastic tuffs and cherty metamorphic quartzite. About 5%.

Groundmass About 80%, altered felsitic textured material plus Epidote and opaques, also fine network of anastomosing sericitic muscovite. Mosaic quartz recrystalisation present as cherty material, and euhedral quartz occurs in vesicle infill. Common yellow epidote as alteration patches in fiamme, and as granular patches in G/mass. Chlorite as alteration of fiamme, mafic minerals and as vesicle infill. Also Calcite as secondary cavity infill.

Field Number	Formation:					
CP55Dα	Ibáñez tuff/Ig (Hornfelsed)					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
276517	4871529	22	10	68		100
Final Rockname						
Albite Epidote hornfels. (Pumice flow/laminated base surge deposit.)						

Microscopic textures (CP55Dα):

Thermally metamorphosed tuff with normally graded crystal and rock fragments in a recrystallised matrix of altered felsitic material and fine grained sericitic mica with moderate bedding parallel SPO.

Crystal and rock fragments are normally graded, from very coarse 2–3mm to medium and fine ash fragments (1mm and less.) and are matrix supported by the sericitic and felsitic recrystallised groundmass.

Quartz is about 12%, angular and broken embayed and rounded beta quartz.

Feldspars are altered, about 10%, now yellow-green epidote, green chlorite and uniaxial -ve colourless material.

Lithic fragments are about 10%, rounded and sub angular oxidised or partly metamorphosed tuff and andesitoid fragments.

Groundmass is mostly sericitic mica and felsitic material with anastomosing bedding parallel shape preferred orientation. About 68% of rock.

Field Number	Formation:					
F19	Ibáñez tuff/Ig?					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
289728	4872533					0
Final Rockname						
Rhyolitic Ignimbritic breccia or Lag breccia.						

Microscopic textures (F19):

Rock is matrix supported, with quartz, feldspar, rock fragmeuts and opaques, with secondary calcite, chlorite, and groundmass with felsitic recrystallised texture, fine grained felsitic/sericitic recrystallised pumices, chlorite and calcite.

Quartz 2–5%, Feldspars, 2–5%, Rock fragmeuts sparse in thin section, more in hand specimen, pebble through to cobbles and boulders, about 40%, trace opaques.

Feldspars are commly cloudy, with alteration to sericite, calcite, chlorite and clays. Quartz is fragmental, rounded and embayed igneous bipyramids. Calcite, chlorite and sericite occur asd feldspar replacement, chlorite and calcite appear as void fillings aud rims. Grauular opaques, ?ilmenite or mangauese oxide, rim some rock fragments and crystal fragments. Rock fragments can be up to 15 mm in the thin section, but hand specimens ranged up to cobbles. Dominated by spherulitic rhyolites, with minor intermediate audesitoids.

A.2.2 Silicic Extrusive Rocks (Including Cerro Cabeza Blanca)

Field Number	Formation:					
CF8D	Ibáñez (Mineralised)					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
273873	4876304					0
Final Rockname						
Mineralised vein in Ibáñez Rhyolite lava.						

Microscopic textures (CF8D):

Crystalline mosaic quartz, some crustiform vein quartz, some drusy cavities, with euhedral aud subhedral elongate prismatic crystals. Ore minerals present are disseminated euhedral and subhedral pyrite cubes, and murky, saw-damaged white galena, almost all ripped out of the slide. Cavities now filled with clay, but field sample had clay.

Field Number	Formatiou:					
CF9D	Ibáñez Breccia					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
273995	4876569					0
Final Rockname						
Brecciated Ibáñez country rock with juvenile matrix associated with Cerro Farellón Complex.						

Microscopic textures (CF9D):

Polymictic breccia with angular crystals and clasts of rhyolitic through andestoid compositions in a matrix of brownish felstitic ash, broken crystal fragments and devitrified material. Esseutially the same as CF9A.

Largest clasts are angular fragments of pilotaxtitic altered andesitoid with green pyroxene, sodic plagioclase, in pilotaxitic textures and altered with a lot of sericite, calcite and chlorite.

Matrix has occasional altered mafics and quartz/sodic plag/andesitic clasts in murky brown devitrifed ashy material.

Occasional clasts of hypabyssal granodioritic rock similar to Cerro Farellón aud Cerro Pirámide intrusives.

Field Number	Formation:					
CF9A	Ibáñez Breccia					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
273995	4876569					0
Final Rockname						
Brecciated andesitic lava mixed with juvenile material related to Cerro Farellón vent breccias?						

Microscopic textures (CF9A):

Polymictic breccia with angular crystals and clasts of rhyolitic through andestoid compositions in a matrix of brownish felstitic ash, broken crystal fragments and devitrified material.

Largest clasts are angular fragments of pilotaxtitic altered andesitoid with green pyroxene, sodic plagioclase, in pilotaxitic textures and altered with a lot of sericite, calcite and chlorite.

Matrix has occasional altered mafics and quartz/sodic plag/andesitic clasts in murky brown devitrifed ashy material.

Occasional clasts of hypabyssal granodioritic rock similar to Cerro Farellón and Cerro Pirámide intrusives.

Field Number	Formation:					
CP31	Ibáñez Breccia					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
277141	4867712					0
Final Rockname						
Thinly to thickly bedded, moderately sorted matrix poor clast supported angular to subangular lithic breccia.						

Microscopic textures (CP31):

Polymictic breccia, clast supported, matrix poor, with angular to subangular moderately sorted clasts of intermediate pilotaxitic textured andesitoids/dacitoids, recrystallised poikilimosaic, felsitic and spherulitic rhyolitoids, quartz and plagioclase crystal fragments, tuff/ignimbrite clasts, quartzite clasts, and occasional granophyre fragments.

Clasts are rimmed with opaque hematite, and cemented with hematite and calcite.

Feldspathic clasts and crystal fragments are altered to sericite and clay, or replaced/invaded by calcite. Mafic phases are chloritise, while opaque minerals are oxidised and replaced by hematite and white leucoxene.

Rock fragments about 60%, comprising 25–30% silicic volcanics, 15–20% intermediate volcanics, 5–8% tuff fragments, 1–2% exotics (quartzite, granophyre.) Crystal fragments about 10%quartz, 10% sodic plagioclase, remainder 20% calcite/hematite rimming, voidfill and matrix/cement material.

Field Number	Formation:					
CF12A	Ibáñez Breccia (Altered)					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
273306	4876512					0
Final Rockname						
Propylitised subvolcanic vent or collapse breccia associated with the Cerro Farellón intrusives and incipient caldera structure.						

Microscopic textures (CF12A):

Breccia of unsorted, angular and fractured crystals and rock fragments, in this section mostly the matrix described in hand specimen, with only one large clast.

Matrix is finely comminuted angular rock fragments, quartz, sericitised felspars, cherty material, mostly sub 0.4mm in grainsize, down to 0.1 or less. Occasional clasts are up to 4–8mm, and the largest is 20mm.

Crystals are fractured or broken quartz and plagioclase, with some quartz showing embayed beta bipyramids. Plagioclase is euhedral, fractured and sericitised.

Sericite and cherty felsitic material form a large part of the matrix. Leucoxene occurs as alteration of opaques.

Many clasts appear to be altered hypabyssal volcanic fragments, but some show granitic textures. Alteration is in the form of mosaic quartz recrystallisation, sericitisation of feldspars, growth of epidote as radial sprays or irregular granular clusters. Pyrite also occurs as euhedral opaque cubes. Calcite occurs as void filling.

Field Number		Formation:					
WI32		Ibáñez Dacitoid					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
271290	4858400		20	25	35	0	80
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
			10	5			
Other components:		Others:	Total:				
sericite, calcite		5	100				
Final Rockname							
Dacitic Breccia/autobreccia.							

Microscopic textures (WI32):

Finely comminuted monomictic breccia of angular pilotaxitic/felsitic textured dacitoid rock, matrix supported in partly recrystallised ashy matrix of felsitic material and smaller clasts, together with crystal fragments and recrystallised secondary quartz.

Clasts are pilotaxitic and flowbanded, with fine grained feldspar laths and felsitic material supporting a few sericitised phenocrysts of sodic plagioclase. Much of felsitic material has RI strongly below epoxy, so it is probably some K-spar and most of the coarser patches recrystallised quartz mosaic. Mafic phases are replaced by chlorite/iron oxides/leucoxene. Clasts are between 0.5 to 10–15mm, unsorted, angular, matrix supported.

Matrix is felsitic material, broken crystal fragments of sericitised or calcite-replaced sodic plagioclase, fine grained opaques, iron oxide, secondary recrystallised quartz mosaic material, sericite, chlorite. Trace chloritised biotite.

Proportions probably clasts: 45–50%, Matrix 50–55%.

% for clast mineralogy: 35% Sodic Plagioclase phenocrysts, groundmass approx 25–30% quartz mosaic, 25% K-spar laths, plus 10% chloritised mafics and 5% opaques.

Field Number		Formation:					
WI34		Ibáñez Dacitoid					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
275130	4859040		20	15	35	0	70
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
			15	5			
Other components:		Others:	Total:				
Calcite etc		10	100				
Final Rockname							
Altered Dacite.							

Microscopic textures (WI34):

Moderately altered porphyritic rock, with euhedral feldspars and altered chloritised mafics in a partly recrystallised felsitic matrix. Similar to WI33, but more feldspars.

Large feldspars are euhedral, often glomeroporphyritic. Crystals are often zoned, and some have sericitised cores or rims. Some sieve textures present. Plagioclase is slightly zoned, with a-—section giving 17, either albite or an25 ish oligoclase. Some plagioclase crystals have irregular or patchy replacement or exsolution of K-spar along cleavage or fractures, and as rims.

Mafics are green, blocky pseudomorphs of chlorite, after pyroxene, from the shape of the pseudomorphs. Often glomeroporphyritic or clustered with opaques, probably magnetite, from blocky shape, or with sericitised plag. Some are uralitised.

Groundmass is poikilomosaic texture with microphenocrysts of feldspar and quartz mosaic with oxidised matrix and disseminated patches of chlorite, hematite and calcite alteration. Calcite patches are more common as halos near some thin fractures filled with secondary mosaic quartz.

Mineral %: Oligoclase & Albite phenocrysts: 20%, 5% for k-spar rims, Opaques (Magnetite)10%, secondary chlorite (after pyroxene) 10%, Groundmass is about 60% of rock, and is about: 5% opaques and oxides, 5% chlorite after mafics, 20% quartz mosaic, 15% partly altered plagioclase microphenocrysts, 10% anhedral K-spar?

Field Number		Formation:					
WI44A		Ibáñez Dacitoid					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
271540	4857820		20	10	60	0	90
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
2			5	3			
Other components:		Others:	Total:				
			100				
Final Rockname							
Dacitic Lava.							

Microscopic textures (WI44A):

Both rocks are porphyritic with an intergranular/ pilotaxitic groundmass, with euhedral and subhedral altered feldspars and mafic minerals in a finer groundmass of partly pilotaxitic feldspar microphenocrysts and granular opaques. Mafics are altered, feldspars partly sericitised or replaced by calcite. Voids are filled with calcite, particularly in 44A, where some areas of matrix are also replaced by calcite. 44B is more altered, although it appeared fresher in the field. Also, groundmass textures iu 44B are much more altered and recrystallised, with a lot of clay about.

Larger Feldspar phenocryst in 44A are euhedral to subhedral, often glomeroporphyritic or complexly twinned, with albite-carlsbad, pericline and some ?synneusis twins. Some crystals have entirely sericitised or calcitised cores, and some weak zoning or rimming occurs. Sieve texture occurs but is rare. Albite or Sodic Oligoclase, large phenocrysts up to 4mm, 20%

Some smaller carlsbad only twinned phenocrysts may be anorthoclase, about 10%, and RI of all feldspars is well below medium. Pilotaxitic and intergrannlar groundmass feldspars are albite twinned, 40% as groundmass microphenocrysts.

Quartz about 15-20% in groundmass mosaics. Also as secondary groundmass alteration.

Mafics are stubby, green pleochroic clinopyroxene, often uralitised or chloritised, perhaps a sodic clinopyroxene.2-3%

Opaques are blocky, square, sometimes with embayments. Probably magenetite.

Groundmass is pilotaxitic Albite microphenocrysts, and granular quartz. Some groundmass material, feldspars included, is recrystallised into irregular mosaic quartz patches, but this is different to the granular material. Also some apatite.

Field Number		Formation:					
WI41 *		Ibáñez Dacitoid					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
270375	4855980		25	15	30	0	70
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
			15	5			
Other components:		Others:	Total:				
Calcite		10	100				
Final Rockname							
Altered Dacitic Lava/Lava Breccia.							

Microscopic textures (WI41):

Porphyritic rock with phenocrysts of chloritised amphibole and sericitised sodic plagioclase in a felsitic groundmass with some patchy quartz mosaic recrystallisation.

Feldspars are euhedral, up to 3mm, but most below 1mm, sometimes glomeroporphyritic, but ubiquitously sericitised or calcite replaced. Some remnants are albite twinned, with low extinction angles, so sodic plagioclase, either albite or Sodic Oligoclase, but not enough to do meaningful measurement.

Mafic phase is elongate or blocky, square pseudomorphs comprised of green pleochroic chlorite and calcite, with some sericite and opaques. From shapes they are more likely to have been pyroxenes, rather than amphibole, because although elongate, they have blocky or square end on sections. Sometimes glomeroporphyritic with blocky opaques (Partly oxidised magnetite) and sericitised plagioclase, plus also slightly brownish apatite.

Groundmass is felsitic material with fine grained disseminated opaques, green altered mafics and some iron oxide staining. Some vague remnants of pilotaxitic texture, and also development of poikilomosaic type quartz mosaic recrystallisation of groundmass.

About 20% sericitised sodic plag, 10% chlorite as altered pyroxene ,65% felsitic groundmass.

Groundmass is approx: 3–5% opaques, about 25% quartz mosaic, 5% altered mafics (now chlorite) and secondary calcite, etc. 10% plagioclase microphenocrysts, perhaps 15% anhedral k-spar.

Field Number		Formation:					
WI113 *		Ibáñez Dacitoid					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
277660	4857300		23	20	45	0	88
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
7				5			
Other components:		Others:	Total:				
			100				
Final Rockname							
Hydrothermally altered and oxidised rhyodacite to rhyolite. (Included with Dacite dome complex because of field relationships.)							

Microscopic textures (WI113):

Weakly flowbanded strongly porphyritic rock, with large, up to 6mm, euhedral altered feldspars, 0.5–1mm euhedralquartz and 2–4mm altered mafic phenocrysts in a partly recrystallised and altered felsitic matrix.

Large feldspars 20% phenocrysts, 45% from groundmass, are 0.5–6mm, euhedral, sodic plagioclase, with some zoning, simple, and most are altered to sericite or calcite, often completely, or cores are sericitised. ML on remnant Albite twins: 12, 15.5, 18? More readings difficult. Looks like most albite twinned crystals are albite or oligoclase. RI of albite twinned felspar both fast and slow are well below medium. Medium is just above fast quartz, equal to slow quartz, which does not help. Probably albite. 20 % phenocrysts — Altered albite, 25% from groundmass.

K-spar 20%?Unknown, probably groundmass anorthoclase or sanidine. Alteration common.

Quartz is present as small, Trace-3% rounded and embayed sub 0.5mm beta quartz bipyramids.

Mafic Phase is blocky, altered crystals, octagonal end section, probably clinopyroxene, now rimmed with Fe oxides, altered in core to calcite, hematite, and pleochroic green ?celadonite, or maybe remnant of uralite. Pseudomorphs only, 5–7%

Trace Alteration products are : Calcite, celadonite, sericite after feldspar, clay, hematite, goethite. Apatite and zircon present as trace minerals.

Groundmass is uniform felsitic material, sometimes oxide stained, and in patches recrystallised to quartz mosaic material, or sometimes replaced with calcite. 60–70%, say 20%quartz, 25%plag, 20% kspar and 5% opaques and trace minerals.

Field Number		Formation:					
WI111 *		Ibáñez Dacitoid					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
278300	4859530		25	15	40	0	80
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
10			5	5			
Other components:		Others:	Total:				
			100				
Final Rockname							
Dacitic dome lava.							

Microscopic textures (WI111):

Porphyritic rock with sodic plagioclase and partly uralitised green clinopyroxene and opaque phenocrysts in a fine pilotaxitic/intergranular feldspar/opaque matrix.

Quartz 25–30% as groundmass patches.

Large sodic plagioclase are euhedral, up to 4mm, sometimes glomeroporphyritic, albite-carlsbad twinned. RI fast and slow directions is below medium, suggesting Albite. Some crystals are slightly sericitised, or have sieve textured or altered cores filled with green chlorite. Albite, phenocrysts up to 4mm, 15%.

Mafics are mostly altered, blocky or tabular crystals, green pleochroic. Unaltered crystals have inclined extinction, up to first order blue d', and appear to be a green clinopyroxene. Looks like uralitic or chloritic alteration to most crystals. Xls up to 0.5mm. 5%

Phenocryst phase opaques are irregular, blocky, often slightly altered/oxidised, and sometimes clustered with uralitised clinopyroxene and/or plag, ± apatite. Probably magnetite, not blobby/skeletal enough for ilmenite.

Groundmass — textures range from pilotaxitic to felsitic, with intergranular opaques. Feldspar microphenocrysts are tabular, sometimes pilotaxitic, albite twinned on occasion, some swallowtailed, with intergranular green pyriboles and fine grained opaques. Anhedral patches of mosaic quartz occur throughout. Estimated groundmass composition: 70–75% of the rock, consisting 15% anhedral low RI k-spar, 25% quartz, 5% altered fine pyroxenes/mafics, 5% opaques, 5% chlorite alteration, 25% Albite microphenocrysts.

Field Number		Formation:					
WI110		Ibáñez Dacitoid					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
277840	4859850		40	20	25	0	85
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
			5	5			
Other components:		Others:	Total:				
Calcite		5	100				
Final Rockname							
Altered Dacitic lava.							

Microscopic textures (WI110):

Porphyritic rock with altered euhedral sodic plagioclase phenocrysts in devitrified and recrystallised quartz-mosaic groundmass, with patches of oxidised opaques and secondary qnartz/calcite alteration patches/zones.

Feldspars are euhedral, up to 3mm, mostly carlsbad-albite twinned sodic plagioclase, often altered or replaced by sericite and calcite, or murky with clays. ML is 15, 17.5, 13, 11, 11.5, 10, 18.5, 17.5. — Albite or Oligoclase. RI fast quartz is above slow Plag, and slow Quartz is quite above fast plag. Looks like Albite.

Some untwinned felspars have RI well below medium, so may be K-spar present as minor phenocryst population.

Blocky patches of opaques and bright green chlorite, and some sericite occur. The opaques are red brown at rims, so hematite or similar. Possibly altered mafics, Pyroxene from blocky shapes?

Common mosaic quartz in groundmass and secondary vein quartz as cavity infill, associated with calcite. Some relict traces of flow-banding, destroyed by Mosaic quartz. Sericite present within some areas of groundmass. Trace green chlorite and some celadonite. Opaque is hematite/goethite.

QAPF difficult, but rock looks like altered dacitoid. Sodic Plagioclase phenocryts: 25%, maybe less. Altered Mafics, 5% or less. Trace to 5% k-spar microphenocrysts. Groundmass is 70% of rock, high in quartz, 40%, although mosaic material has patchy look that may result from original spherulitic texture, and other mineral with quartz in patchy areas has low RI, so anhedral k-spar, 20%, plus secondary calcite, 5% opaques 5%, plus some void filling euhedral quartz.

Field Number	Formation:					
WI36B	Ibáñez Dacitoid (Altered)					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
275525	4858035					0
Final Rockname						
Altered and chloritised breccia of Juvenile dacitic fragments.						

Microscopic textures (WI36B):

Strongly altered rock with large rounded clasts of vesicular dacitoid rock with sericitised phenocrysts of plagioclase and matrix/groundmass of similar composition, also vesicular, with murky altered groundmass of pilotaxitic and felsitic material with much secondary chloritisation of any mafics, and some mosaic quartz recrystallisation, particularly along clast rims.

Clasts and matrix are strongly vesicular, with vesicles infilled with radial platy green chlorite clusters, or rimmed with opaques and filled with calcite.

Feldspars are about 40%, up to 3mm, euhedral and subhedral, commonly glomeroporphyritic, altered to sericite and replaced by calcite. Remnant albite twinning has low extinction angles, indicating sodic plagioclase.

Secondary alteration minerals include calcite, quartz, hematite, sericite, leucoxene, etc.

Too altered for accurate QAPF

Field Number		Formation:					
WI45A		Ibáñez Dacitoid (Altered)					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
271990	4858540		20	15	40	0	75
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
			10	5			
Other components:		Others:	Total:				
Calcite		10	100				
Final Rockname							
Altered dacite lava.							

Microscopic textures (WI45A):

Porphyritic rock with felspar aud altered mafic phenocrysts in a dark, mafic rich intergranular groundmass with felsitic and pilotaxitic textures, with some calcite or chlorite filled vesicles.

Plagioclase is euhedral, but cores are altered to sericite or chlorite, and some may be rimmed with k-spar. Generally too altered for extinction angle tests, but RI against medium indicates Sodic Plagioclase or Albite., and the becke line on the rims is almost strong enough for K-spar anorthoclase rimming.

Mafics are uniformly altered to pleochroic blue-green chlorite and/or uralite, also reddish hematite stainiug. Blocky rectangular crystals make me thiuk these are uralitised and chloritised cliuopyroxeues.

Blocky patches of brownish aud red rimmed hematite and goethite opaques may be oxidised Magnetite phenocrysts.

Groundmass is murky felsitic material with some quartz mosaic recrystallisiation, pilotaxitic altered feldpsar microphenocrysts and oxidised opaques, now mostly haematite/goethite. Feldspars are sericitised. Voids are filled with either goethite/calcite mix, or green/brown amorphous material.

Sodic plag: 25%. Altered clinopyroxene (chlorite/uralite) 10%, Hematite/goethite (after Opaques, probably magnetite.) 5% Secondary calcite/voidfill 10%. Groundmass is 50% of rock, aud is probably about 20% quartz mosaic, 15% euhedral sodic plagioclase microphenocrysts and 15% anhedral groundmass K-spar with the quartz mosaic (some patches give other than uniaxial negative figures and have low RI.)

Field Number	Formation:					
WI44B	Ibáñez Dacitoid (Altered)					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
271540	4857820					0
Final Rockname						
Altered Dacite lava.						

Microscopic textures (WI44B):

Both rocks are porphyritic with an intergranular/ ilotaxitic groundmass, with euhedral and subhedral altered feldspars and mafic minerals in a finer groundmass of partly pilotaxitic feldspar microphenocrysts and granular opaques. Mafics are altered, feldspars partly sericitised or replaced by calcite. Voids are filled with calcite, particularly in 44A, where some areas of matrix are also replaced by calcite. 44B is more altered, although it appeared fresher in the field. Also, groundmass textures in 44b are much more altered and recrystallised, with a lot of clay/calcite about.

Larger Feldspar phenocryst in 44A are euhedral to subhedral, often glomeroporphyritic or complexly twinned, with albite-carlsbad, pericline aud some ?synneusis twins. Some crystals have entirely sericitised or calcitised cores, and some weak zoning or rimming occurs. Sieve texture occurs but is rare. Smaller phenocrysts without zoning, sieve texture and without much alteration appear to be K-spar, type not certain. RI of all feldspars is well below medium.

Mafics are stubby, green pleochroic clinopyroxene, often uralitised or chloritised. Perhaps a sodic clinopyroxene.

Opaques are blocky, square, sometimes with embayments. Probably magnetite.

Groundmass is pilotaxitic feldspar microphenocrysts, probably K-spar, and unknown granular colourless mineral — maybe quartz but could also be groundmass foid. Some groundmass material, feldspars included, is recrystallised into irregular mosaic quartz patches, but this is different to the granular material. Also some apatite.

Field Number	Formation:					
WI37	Ibáñez Dacitoid (Altered)					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
275570	4857710					0
Final Rockname						
Altered Dacitic Lava.						

Microscopic textures (WI37):

Altered dacitic rock, with phenocrysts of sericitised sodic plagioclase, chloritised mafics, microphenocryst of magnetite and apatite, in a groundmass of pilotaxitic feldspars with occasional anhedral quartz, with common secondary calcite, sericite, clay and chlorite.

Feldspars are euhedral to subhedral sericitised sodic plagioclase, up to 3mm, brownish aud murky in ppl, sometimes glomeroporphyritic. Remnant crystals with Albite twius give angles between 10 and 7, while RI of both fast and slow directions is below epoxy, so Albite. About 30% of the rock.

Mafic phase is entirely altered to platy pleochroic bright green chlorite, with straight extinction and anomalous blue interference colours. Pseudomorphs thus formed are blocky, square or tabular shapes, with some remnants having octagonal end sections, indicating that this phase was a pyroxene, probably clinopyroxene.

Associated with the altered pyroxenes are blocky magnetite crystals, often oxidised (up to 0.5mm, max) and low birefringence apatite crystals.

Groundmass has common hematite oxide stainiug, and ubiquitous calcite aud chlorite alteration and void-filling. Sericite is commou, especially at grain boundaries. Primary mineralogy is iutergranular or pilotaxitic feldspar microphenocrysts with intergranular mafics (now oxidised or chloritised), opaques, and interstitial anhedral quartz, plus minor accessory apatite. Microphenocryst feldspar is mainly plag, although the high sericite level may indicate a lot of altered k-spar.

Too altered for accurate QAPF.

Field Number	Formation:					
WI36A	Ibáñez Dacitoid (Altered)					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
275525	4858035					0
Final Rockname						
Altered and silicified Dacitic Lava Breccia.						

Microscopic textures (WI36A):

Altered, possibly partly hornfelsed dacitic rock, with original mineralogy of euhedral 1–2mm sodic plagioclase phenocrysts in a groundmass of felsitic material, but now with many patchy recrystallisation and replacment areas of calcite and mosaic quartz, following flowbanding.

Feldspars are blocky euhedral and subhedral sodic plagioclase, up to 2mm, about 15–20%. Most now eroded and replaced by plagioclase, or clays/sericite. RI is below epoxy, so probably Albite.

Quartz is ubiquitous as recrystallised mosaic material in groundmass, or vein/cavity euhedral crystals with the large calcite patches.

Groundmass felsitic texture is partly replaced by sericite, quartz mosaic and calcite. Opaques are oxidised, and red hematite staining is common. Some groundmass sericite has coarsened up and recrystallised to form 0.5mm muscovite porphyroblasts.

Too altered for accurate QAPF.

Field Number	Formation:					
WI87	Ibáñez Dacitoid (Altered)					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
271890	4864430					0
Final Rockname						
Propylitised Dacitic dome or sill.						

Microscopic textures (WI87):

Entirely altered rock. Porphyritic textures remain, but large feldspars have been altered and replaced by sericite and goethite/hematite to form pseudomorphs. Groundmass is coarsened felsitic texture with recrystallised quartz, sericitised feldspars and iron oxides, with occasional recrystallisation of the sericite into visible muscovite.

?Propylitised Dacitic dome or sill? Too fine graine for QAPF.

Field Number	Formation:					
WI33 *	Ibáñez Dacitoid (Altered)					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
271736	4858660					0
Final Rockname						
Altered dacite or trachyte. Chemistry is trachyte field ou TAS, but greater than 20% normative quartz makes it more dacitic, and the TAS plot may reflect the high alteration level.						

Microscopic textures (WI33):

Porphyritic rock with occasional sericitised feldspars, altered green mafic minerals and felsitic textured groundmass with remnants of pilotaxitic texture. Section may be cut too thin, as all feldspars appear to be ripped out.

Feldspars are euhedral, some remnants have 2vx 20-6-0, OAP parallel to O10, so maybe high sanidine present. Others are sodic plagioclase, but most are to altered to tell. Alteration is sericite, calcite, or cherty material. Many feldspars have been ripped from the section during preparation.

Mafics are bright pleochroic blue green, blocky crystals with occasional eight sided section. Appear to be uralitised pyroxene, from shape of some sections. Some are chloritised and surrounded by reaction rim of opaques. May be a sodic amphibole, but no cleavage visible. Colour suggests this, though.

Groundmass is felsitic devitrified material, with fine grained opaques, possibly aenigmatite, and patches of quartz, perhaps some feldspar, as combined mosaic rexllisation. Some sparse low RI material could be zeolite.

Too altered for reliable QAPF estimations.

Field Number		Formation:					
L7		Ibáñez Dacitoid (Altered)					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
281909	4858458		35	20	40	0	95
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
				5			
Other components:		Others:	Total:				
			100				
Final Rockname							
Altered rhyolitic lava.							

Microscopic textures (L7):

Porphyritic rock with altered feldspar phenocrysts in felsitic to partly mosaic recrystallised poikilomosaic groundmass with irregular patches and spots of opaque hematite/goethite.

Feldspar phenocrysts are euhedral, slightly rounded, sometimes glomeroporphyritic. Up to 3mm, altered with brownish clay patches, Albite and Carlsbad twinned. RI fast and slow well below Epoxy, so probably Albite. Some sericite, and occasional patchy replacement by calcite. About 10%.

Groundmass is faintly pilotaxitic, with microphenocrysts of altered plagioclase in pilotaxitic texture defining faint flowbanding, with most of the groundmass showing felsitic texture incipiently recrystallised to quartz mosaic or poikilomosaic textures. About 30% microphenocrysts of plag, 35% quartz mosaic, 20% K-spar in anhedral felsitic texture with the recrystallised quartz, 5% or so altered hematite and leucoxene after mafic phases. Minor secondary calcite and sericite.

Field Number	Formation:					
F55	Ibáñez Dacitoid (Altered)					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
280250	4868375					0
Final Rockname						
Hydrothermally altered dacitic — rhyodacitic lava.						

Microscopic textures (F55):

Pervasively altered rhyolitoid or dacitoid. Feldspars are replaced by clays, calcite, etc, often haloed by opaque or dark brown iron oxides. Quartz occurs as small (.2–0.4 mm) microphenocrysts in the groundmass, about 5%.

Feldspars are euhedral and subhedral rounded crystals up to 3mm, some glomeroporphyritic clusters, about 8%, and are pseudomorphed by calcite and brown patchy hematite.

Gronndmass is fine grained felsitic material, partly recrystallised to mosaic quartz, with disseminated fine opaque iron oxides and yellow staining, with patches of calcite, and perhaps also siderite. Section cut a little thick, quartz is too yellow or even red.

Too altered for QAPF. Lack of common large phenocryst quartz may indicate dacitic to rhyodacitic composition, rather than rhyolitic.

Field Number	Formation:					
WI18	Ibáñez Dacitoid (Altered)					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
274580	4864030					0
Final Rockname						
Propylitised Dacite to rhyodacite.						

Microscopic textures (WI18):

Sparsely porphyritic altered rhyolite or rhyodacite. Sparse altered feldspar phenocrysts and recrystallised quartz in an altered, goethite/haematite stained felsitic or pilotaxitic matrix.

Large feldspars, about 10%, up to 2mm are euhedral, sometimes glomeroporphyritic, murky and often sericitised or with patches of calcite. RI suggests Albite, or more likely K-feldspar, but there are some albite twinned crystals, and some Carlsbad only twinned crystals. Probably a mix of the two. Some crystals have 40–60 2v and oap — 010, so probably anorthoclase, while those with 2v as high as 80, are probably albite. Alteration makes identification difficult.

Quartz occurs as murky mosaic patches in the groundmass, also as reccrystallised clear mosaic and euhedral quartz in cavities with calcite. No phenocryst quartz.

Muscovite is common as coarsened and recrystallised material from sericite, and disseminated sericite is very common in groundmass.

Remainder of groundmass is pilotaxitic sericitised feldspars, sometimes with faint albite or carlsbad twin remnants, with RI well below epoxy, in murky poikilomosaic quartz, sericite, and dominant opaques are brown goethite and opaque reddish hematite.

Too fine grained and altered for accurate QAPF.

Field Number	Formation:					
WI107A	Ibáñez Dacitoid (Altered)					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
276136	4857940					0
Final Rockname						
Propylitised/hydrothermally altered Dacitic Lava.						

Microscopic textures (WI107A):

Flowbanded porphyritic rock, with altered feldspar pseudomorphs in a recrystallised quartz/feldspar mosaic matrix.

Large (up to 3mm) feldspars are euhedral laths or tablets, almost all are altered to sericite, clay or calcite, particularly calcite in cores, and some crystals entirely replaced by calcite. Also replacement by cryptocrystalline or mosaic qnartz.

1mm patches or blobs of hematite occur, often with diffuse halo of goethite staining. Some occurs with muscovite in what may be pseudomorphs of biotite, while some replaces square, blocky mineral that was probably magnetite.

Groundmass is recrystallised to felsitic or mosaic qnartz with interstitial opaques and sericite, plus trace tridymite plates and occasional zircon.

QAPF not feasible.

Field Number		Formation:					
WI76 *		Ibáñez Rhyolitoid					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
269410	4864870		45	40	13	0	98
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
				2			
Other components:		Others:	Total:				
			100				
Final Rockname							
Rhyolite dike, recrystallised and silicified.							

Microscopic textures (WI76):

Flowbanded, porphyritic rock with 3–5% quartz and feldspar phenocrysts in a thoroughly recrystallised quartz mosaic flowbanded groundmass. Feldspars are altered and replaced by calcite/sericite, and some blocky masses of calcite/opaques may be pseudomorphs of a mafic mineral, perhaps biotite or pyroxene.

Quartz phenocrysts are rounded and embayed bipyramids, sometimes fractured, 5%, up to 2mm. Some phenocrysts have overgrowth of groundmass murky mosaic quartz, in optical continuity, while others are overgrown by halos of recrystallised mosaic groundmass, and may have been at the centre of spherulites.

Feldspars are 5–8%. often altered, euhedral/subhedral, replaced by calcite or sericite. 2v ranges from 90 ish to 30–40 -ve. Albite twinned crystals are sparse, but indicate sodic oligoclase or albite, and have RI strongly below medium — probably albite.

Mafic pseudomorphs (Calcite/hematite) and opaques, 1–2%.
Groundmass is recrystallised to mosaic quartz, although in ppl there are some structures visible, such as flowbanding and flattened/attenuated vesicles, and occasional recrystallised spherulites. Flowbanding is now expressed in grainsize variations of the mosaic quartz.
Approximate QAPF: Phenocryst quartz: 5%, Phenocryst plag: 8% Altered mafics and opaques: 2% Groundmass remaining 85 % of rock, so about 40% each mosaic Quartz and anhedral K-spar, 5% altered plagioclase microphenocrysts.

Field Number WI59		Formation: Ibáñez Rhyolitoid					
Utm East 270950	Utm North 4867290		Q: 40	A: 35	P: 23	F: 0	Subtotal: 98
Cpx:	Opx:	Amph:	Chlorite:	Opaques: 2	Muscovite:	Biotite:	Olivine:
Other components:		Others:	Total: 100				
Final Rockname Spherulitic and felsitic rhyolite dike.							

Microscopic textures (WI59):

Porphyritic rock with phenocrysts of quartz, glomeroporphyritic feldspar and altered ?biotite in a recrystallised felsitic matrix, with remnant spherulites, quartz mosaic rexlln and seams of goethite and patches of disseminated calcite.
Quartz phenocrysts are 0.5–3mm 3–5%, rounded, euhedral to subhedral bipyramids, occasionally embayed or fractured. Some are twinned, and some have overgrowths of fibrous quartz/kspar as incipient spherulites from groundmass devitrification.
Feldspars are euhedral/subhedral, often glomeroporphyritic, up to 5mm across, 5–8%. Alteration is patchy replacement with calcite and sericite, calcite more common, often in blebs and lamellae along crystal structures/cleavages. Most display albite or carlsbad twins, Albite or Sodic plag. Some have carlsbad twinning only. Medium RI is between fast and slow quartz, carlsbad-albite twinned feldspar is strongly below medium.
Possible biotite pseudomorphs are blocky patches of goethite/hematite/muscovite/leucoxene, with iron rich material approximately parallel to what would have been cleavage directions if the material was once biotite. Up to 1mm, trace.
Groundmass is felsitic material, partly recrystallised to quartz mosaic, but still displaying occasional patches of altered spherulites , altered albite microphenocrysts. Trace epidote, plus occasional zircon. Some sericitic mica, patches of calcite also. Also seams of opaque goethite.
Approximate QAPF: Phenocryst quartz: 5%, Phenocryst Plag: 8%, opaques as hematite pseudomorphs after biotite, and altered groundmass opaques, 2%. Remaining groundmass: 85% of rock, with about 15% albite microphenocrysts, 35% each Quartz and altered K-spar.

Field Number CP71		Formation: Ibáñez Rhyolitoid					
Utm East 275672	Utm North 4869296		Q: 58	A: 30	P: 10	F: 0	Subtotal: 98
Cpx:	Opx:	Amph:	Chlorite:	Opaques: 2	Muscovite:	Biotite:	Olivine:
Other components:		Others:	Total: 100				
Final Rockname Devitrified and recrystallised rheomorphic lava, perhaps sourced from a rhyolitic ignimbrite. Or highly vesicular rhyolite. ?Silicified.							

Microscopic textures (CP71):

Porphyritic rhyolite with rounded and embayed subhedral quartz and sericitised feldspar phenocrysts in a flowbanded felsitic matrix, with well developed, recrystallised quartz mosaics pseudomorphing earlier eutaxitic or pseudo-eutaxitic texture.
Quartz phenocrysts are rounded or embayed subhedral beta quartz shapes, up to 2mm across.
Feldspars are sparse, entirely altered euhedral/subhedral fragments, sometimes fractured. Most are altered to sericite.
Groundmass is streaky, flowbanded brown glassy material in ppl, with strong eutaxitic texture. CPL reveals that large lenses in this texture are recrystallised to mosaic quartz,and some sericite, while the brown glassy material has devitrified to felsitic material. Well developed wrap around structures occur with phenocrysts, and some of the recrystallised lenses have extensional pull apart cracks preserved.
Approx QAPF: Phenocryst quartz: 8%, Feldspar Pseudomorphs 10%. 1–2% opaques. Groundmass: 80% of rock, about 20% clear mosaic quartz and 60% murky recrystallised felsitic material estimated to be 30% each quartz/k-spar. If feldspar phenocryst pseudomorphs are assumed to be sodic plagioclase, numbers are quartz 58, plagioclase 10, kspar 30.

Field Number		Formation:					
CP30		Ibáñez Rhyolitoid					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
276983	4868054		35	30	30	0	95
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
			1	3			
Other components:		Others:	Total:				
Sericite		1	100				
Final Rockname							
Rhyolite lava.							

Microscopic textures (CP30):

Fine grained rock with sparse small quartz and feldspar phenocrysts in a mixed groundmass of felsitic material with microphenocrysts of feldspar and quartz.

Quartz phenocrysts are sparse, less than 0.4mm, rounded or fractured. About 5%.

Larger feldspars are slightly altered, euhedral to snbhedral fractured crystals, up to 0.5 mm, 2v moderate-high, about 70. Albite twinned, RI of fast and slow is below epoxy. (1.54) Probably Albite or albite twinned sodic k-spar. About 5%.

Groundmass is fine felsitic texture with pilotaxitic flow aligned feldspar microphenocrysts, with albite-carlsbad twinning. Common coarsening or recrystallisation of felstitic material to poikilomosaic quartz and murky low RI anhedral feldspar, probably k-spar. Some small patches of green-yellow chlorite? And sericitised material. Opaques are oxidised to goethite-limonite.

Microphenocryst feldspars are euhedral laths, carlsbad and albite twinned, but ML is about 6–8, so either Albite or Oligoclase. RI fast and slow below medium, so Albite.

QAPF about 5% each phenocrysts quartz and albite. Groundmass is 90% of rock, with about 20–25% pilotaxitic plagioclase microphenocrysts, 3% altered opaques and 2% secondary chlorite/sericite, 30% quartz mosaic, 30% murky altered k-spar, anhedral crystals.

Field Number		Formation:					
F22 *		Ibáñez Rhyolitoid					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
287090	4868960		40	37	10	0	87
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
				5		3	
Other components:		Others:	Total:				
Devitrified Glass		5	100				
Final Rockname							
Spherulitic Rhyolite Lava.							

Microscopic textures (F22):

Porphyritic rock with phenocrysts of sodic plagioclase, quartz and biotite in a groundmass of mosaic spherulites and fine grained microlites.

Quartz phenocrysts are rounded, embayed or skeletal and fractured beta quartz pseudomorphs, about 3–5%, up to 2mm.

Feldspar phenocrysts are euhedral to subhedral partly rounded crystals, sometimes fractured, Albite, Carlsbad aud pericline twinned, partly altered to clay/sericite. Up to 3mm, 5–10%. Not enough crystals to do reliable extinction angle tests, but most twinned crystals have low angles (10–15 degrees) and Rl of fast and slow is below epoxy, so probably albite.

However some small, untwinned crystals have high 2v and oap parallel to 010, so maybe a 1–2% of Sanidine present.

Biotite is altered, green-brown, partly chloritised and with opaque material exolved along cleavage plains. 3%, 1mm and less in size.

Groundmass is dominated by partly recrystallised mosaic spherulitic texture. Spherulites are nucleated on most phenocrysts, or randomly. Mosaic spherulites cover most area, although some areas of felsitic texture occur where spherulites have not nucleated. Trace perlitic cracking shows that these felsitic areas were once glass. Two generations of microlites occur, one set parallel to wavy even flowbanding that passes through spherulites, and other set radially orientated on spherulites. Quartz mosaic recrystallisation has occurred randomly in spherulitic material, but also in bands and veins along spherulite mosaic boundaries and along fractures.

QAPF approx: Phenocryst quartz 5%, Phenocryst Albite 10%, Phenocryst Sanidine 2%., Biotite 3%, Groundmass about 80% of rock, so about 35 Quartz, 35% K-spar, 5% felsitic devitrified glass and 5% microlites and opaque hematite.

Field Number		Formation:					
GA11C *		Ibáñez Rhyolitoid					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
288426	4871485		44	34	15	0	93
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
				2		5	
Other components:		Others:	Total:				
			100				
Final Rockname							
Biotite bearing spherulitic Rhyolite lava.							

Microscopic textures (GA11C):

Striking Porphyritic rock with quartz, feldspar and biotite phenocrysts in a bright red-brown spherulitic matrix. Very pretty.

Quartz phenocrysts are irregular, up to 10%, 0.5–3mm rounded and strongly embayed crystals. Some embayments retain isotropic brown glass.

Feldspars are large, euhedral to subhedral/rounded, most 0.5–3mm, some glomeroporphyritic clusters up to 5mm across. Alteration is common, with ubiquitous partial replacement by patchy, blebby calcite, but also with mosaic quartz or sericite. Difficult to identify due to alteration, but remnant Albite carlsbad twinned material has RI strongly below medium, so most likely Albite , about 15% of rock .

Biotite is dark brown to red brown pleochroic, in tabular euhedral books or hexagonal basal sections. Basal sections are almost black. Up to 1.5mm, 2–5% Some biotite is altered, to tabular pseudomorphs outlined with iron oxides, filled with mosaic quartz.

Groundmass is 70 % of the rock, brown mosaic spherulitic material, sometimes partly recrystallised to mosaic quartz, but near phenocrysts spherulites are several mm across. Trace Apatite and zircon. Some patches of felsitic and quartz mosaic material occur, between rounded spherulites. Spherulites/felsitic material is 70% of rock, so is estimated to be about 2% fine opaques and microlites, and about 34% each quartz and k-spar in anhedral felsitic material or radial spherulites.

Field Number WI25 *		Formation: Ibáñez Rhyolitoid					
Utm East 270150	Utm North 4862670		Q: 43	A: 35	P: 20	F: 0	Subtotal: 98
Cpx:	Opx:	Amph:	Chlorite:	Opaques: 2	Muscovite:	Biotite:	Olivine:
Other components:		Others:	Total: 100				
Final Rockname Partly altered and recrystallised Rhyolite Lava dome or cryptodome.							

Microscopic textures (WI25):

Porphyritic rhyolite with rounded and embayed quartz phenocrysts, feldspars (altered), in a fine felsitic groundmass which shows flow-banding through grain size variations in the groundmass.

Quartz is rounded, subhedral crystals, 0.5–3mm, often embayed, sometimes fractured. Some crystals are overgrown with optically continuous halo from partly recrystallised felsitic material in groundmass. About 5–8%.

Feldspars are rounded, subhedral to euhedral pseudomorphs, up to 3mm, entirely replaced by sericite with some patches of calcite and opaques. May have been sodic plagioclase. Up to 3mm, about 5%.

Some mafics, from blocky shape possibly pyroxene, now pseudomorphed by green pleochroic chlorite and sericite.

Groundmass is very fine grained felsitic material, now recrystallised to murky mosaic quartz, some of which has overgrown phenocrysts, with occasional round patches of secondary recrystallised quartz after spherulites, and altered microphenocrysts of feldspar. Occasional veins and patches have clear mosaic quartz and fine sericitic mica. Opaques are altered to hematite and goethite oxide stains.

Approximate QAPF: Phenocryst quartz, 8%, Phenocryst sericitised plag, 5%. Altered mafics and opaques, 1-2%, Groundmass 85% of rock, with about 15% altered ?plagioclase microphenocrysts and 35% each quartz/kspar in partly recrystallised felsitic texture.

Field Number L14 *		Formation: Ibáñez Rhyolitoid					
Utm East 284040	Utm North 4860840		Q: 50	A: 26	P: 15	F: 0	Subtotal: 91
Cpx:	Opx:	Amph:	Chlorite:	Opaques: 9	Muscovite:	Biotite:	Olivine:
Other components:		Others:	Total: 100				
Final Rockname Flowbanded rhyodacitic to rhyolitic lava.							

Microscopic textures (L14):

Porphyritic rock with sericitised phenocrysts of feldspar in a mosaic quartz recrystallised groundmass. No quartz phenocrysts, and sparse blocky opaques and ocassional blocky mafic pseudomorphed by green pleochroic chlorite. Common oxide staining and patches of dark brown semi-opaque hematite.

Feldspars are euhedral and subhedral phenocrysts up to 2mm, and are altered to sericite, calcite and clays. Unaltered crystals show some albite twinning, and have RI well below the epoxy mounting medium. Most remnant crystals appear to be albite, with low RI albite twins, while other crystals have no albite twins, very low RI, and OAP parallel to 010, and may be high sanidine k-feldspar.

Groundmass is well recrystallised mosaic quartz and altered low RI anhedral k-spar in coarsened mosaic, perhaps recrystallised a bit from felsitic or spherulitic texture. K-spar is quite murky and altered.

Approx composition Albite phenocrysts: 15%, Sanidine phenocrysts: trace to 1%. Opaque phenocrysts and altered mafics: 5%. Groundmass: 80% of rock, approx 50% quartz, 25% altered anhedral k-spar, and 3–4% altered opaques aud secondary hematite after opaques/mafics.

Field Number		Formation:					
F18 *		Ibáñez Rhyolitoid					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
288375	4871800		50	35	10	0	95
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
				3		2	
Other components:		Others:	Total:				
			100				
Final Rockname							
Rhyolite feeder dike.							

Microscopic textures (F18):

Porphyritic flowbanded rock with phenocrysts of quartz and sericitised feldspar, in a groundmass of flowbanded and quartz-mosaic recrystallised material. Traces of muscovite/opaques as pseudomorphs of biotite.

Quartz phenocrysts are euhedral, rounded and embayed beta quartz bipyramids, up to 2mm, about 5%.

Feldspar phenocrysts are euhedral-subhedral, but completely altered to sericite, in fine grained masses forming pseudomorphs of the feldspar crystals, with some glomeroporphyritic crystals up to 3mm, again, about 10%. No phenocrysts are unaltered, so original feldspar phenocryst composition is unknown, but probably sodic plagioclase.

Trace Muscovite, grown with opaques along cleavage plains, perhaps pseudomorphing biotite.

Groundmass — flowbanded and recrystallized poikilomosaic quartz and murky feldspar after spherulites. Spherulitic textures are visible in ppl as round and elongate spherulites along flowbanding, or nucleated on phenocrysts, but have been obliterated by mosaic quartz recrystallisation in cpl. Fine opaques and remnant feldspar occur.

Approximate QAPF: Quartz, 50%, Sodic Plagioclase 10%, Biotite pseudomorphs 2% or less, K-spar in groundmass about 35%. Opaques 3%.

Field Number	Formation:					
WI6	Ibáñez Rhyolitoid (Altered Vein at Margin)					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
278700	4862900					0
Final Rockname						
Unusual calcite vein replacment of chilled margin of rhyolitic intrusive.						

Microscopic textures (WI6):

Rock is composed almost entirely of calcite, both sparry and microcrystalline, with some radial structures perhaps pseudomorphing spherulites, and some small pod-like structures that may indicate bacterial colonisation in the veins. One phenocryst of volcanic quartz occurs. Some dissolution seams or stylolites occur.

Field Number	Formation:					
F13	Ibáñez Rhyolitoid (Altered)					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
289468	4869995					0
Final Rockname						
Devitrified and recrystallised flowbanded Rhyolite. (Part of feeder system for C. Cabeza Blanca.)						

Microscopic textures (F13):

Rock is thoroughly recrystallised and devitrified flowbanded rhyolite. Felsitic matrix has been recrystallised into quartz mosaic, sparse feldspar phenocrysts are completely altered to fine grained sericite.

Feldspar phenocrysts are euhedral to subhedral, sericitised, with remnant fragments showing albite twinning occasionally. Crystals were up to 2mm, and about 5% of the rock.

Quartz is not present as a phenocryst phase.

Opaques are up to 0.5mm, anhedral or blebs, altered to brown hematite or white leucoxene. 1%.

Groundmass is up to 90–95% of the rock, and is felsitic to mosaic quartz/altered feldspar in variable degrees of recrystallisation, apparently controlled by flowbanding. Grain size varies from unrecrystallised felsitic material with patches of mosaic quartz up to .5mm, through to moderately recrystallised poikilomosaic material with .2–0.5mm mosaic quartz, up to coarsely recrystallised poikilomosaic quartz with 0.5 to 1mm size crystals. The feldspathic portion of the groundmass is low RI, murky and altered.

QAPF not feasible

Field Number	Formation:					
F15A	Ibáñez Rhyolitoid (Altered)					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
289370	4867606					0
Final Rockname						
Altered and silicified rhyolite.						

Microscopic textures (F15A):

Same mapping unit as F3. Recrystallised and altered flowbanded rhyolite, porphyritic with glomeroporphyritic altered feldspars roughly aligned along flowbanding orientation. Large patches of calcite occur as voidfilling of drusy quartz lined voids.

Large phenocryst feldspars are euhedral tablets and laths, albite-carlsbad twinned and often partly or wholly altered to sericite and calcite. Often glomeroporphyritic in clusters along flowbanding orientation, now altered and surrounded by groundmass mosaic quartz. RI medium is between fast and slow quartz, large feldspar phenocrysts are strongly below epoxy, albite twinned crystal — 2vx moderate, So high Albite.

3–5% patches of round or anhedral brownish opaque hematite.

Groundmass is fine felsitic material, with some pilotaxitic fine carlsbad twinned felspar, and some disseminated or vein filling sericitic mica. Some sericitic mica has coarsened up and formed sizeable crystals (up to 0.3mm) Around phenocrysts, groundmass is recrystallised into quartz mosaics, murky, but sometimes clear, forming poikilomosaic texture with microphenocrysts of feldspar. Some of these poikilomosaic patches are round, and may be recrystallised spherulites. RI of microphenocrysts within this quartz is strongly below the quartz, so probably albite or K-feldspar. Trace zircon.

QAPF not feasible.

Field Number		Formation:					
L19		Ibáñez Rhyolitoid (Altered)					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
284100	4859800		30	25	30	0	8
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
				5			
Other components:		Others:	Total:				
Calcite/apatite/sericte		10	100				
Final Rockname							
Weathered rhyodacitic/rhyolitic Dome lava.							

Microscopic textures (L19):

Oxide stained porphyritic rock. Matrix and phenocrysts are stained brown in ppl by iron oxides, and original opaque minerals are altered to haematite/goethite or white leucoxene.

Feldspars are euhedral, 0.2–2mm max, 15%. Albite and Carlsbad/albite twins common. ML: 18.5, 17, 16.5, 8, 7, 21.5, RI of albite twinned crystals, Fast below medium, Slow just above. An% just below 30 — Calcic oligoclase, 15%. Alteration quite pervasive, crystals are murky with clays and have patches of sericite and calcite.

Some of the smaller phenocrysts and microphenocrysts display only carlsbad twins, and may be k-spar, but not much (?anorthoclase, trace to 5%)

Groundmass is murky brown material, recrystallised to quartz mosaic which is poikilomosaic textured about altered albite twinned felspar microphenocrysts. 70% of rock, about 15% altered plagioclase microphenocrysts, 5% hematite and leucoxene after opaques and about 30% mosaic quartz and 20% murky altered K-spar

Opaques are altered to leucoxene or goethite/hematite. Trace minerals include apatite and sericitic mica. A mafic mineral has been replaced by mix of calcite, goethite and leucoxene.

Field Number	Formation:					
CP20 *	Ibáñez Rhyolitoid (Altered)					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
277955	4869685					0
Final Rockname						
Altered spherulitic rhyolite lava breccia.						

Microscopic textures (CP20):

Brecciated spherulitic rhyolite, with slightly recrystallised blocks of spherulitic material held in a matrix of finer fragments and recrystallised felsitic to quartz mosaic material

Feldspars are rare as phenocrysts, less than 10%, and are sericitised to fine sericite withont exception. Some are euhedral, some fractured subhedral.

Rare broken beta quartz phenocrysts occur.

Spherulites are radial or irregular, 3–5mm, with occasional partly recrystallised cores, but otherwise well preserved.

Recrystallisation to murky felsitic material and quartz mosaics is common, especially within matrix material, but not so much within breccia blocks, and then mainly between spherulites, rather than within them. Small quartz veins with clear mosaic quartz are common.

Square, blocky pyrite crystals occur, often oxidised with goethite halo.

Too altered for QAPF.

Field Number	Formation:					
CP25C	Ibáñez Rhyolitoid (Altered)					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
277775	4868796					0
Final Rockname						
Altered Spherulitic Rhyolite.						

Microscopic textures (CP25C):

Devitrified and recrystallised quartz rich felsitic matrix dominates this rock. Texture is a flowbanded, sparsely porphyritic rhyolite, with occasional sodic plagioclase feldspars replaced by sericite and calcite. Groundmass is fine, granular to cherty quartz mosaic with occasional remnant feldspar, cherty material, sericitic muscovite, and calcite.

Feldspar phenocrysts are subhedral to euhedral, 0.5–3mm, sometimes fractured, about 8–10%, replaced with patchy calcite, quartz, sericite and occasional muscovite plates. No albite twinning visible, although some carlsbad twins remain. RI both fast and slow is strongly below epoxy, so K-spar. 2v difficult, but crystals are negative.

Flowbanding is preserved by grainsize variations in the cherty quartz groundmass, while spherulites are present as recrystallised spherical agglomerations of mosaic quartz and sericite.

Fine platy muscovite/sericite in the groundmass is sub parallel to the original flowbanding.

Too altered for accurate QAPF, but looks like a very silicic alkali feldspar rhyolite.

Field Number	Formation:					
CP36B	Ibáñez Rhyolitoid (Altered)					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
278288	4867515					0
Final Rockname						
Silicified rhyolitic lava.						

Microscopic textures (CP36B):

Altered rhyolitic rock, with well developed mosaic quartz defining remnant flowbanding texture by grain size variations, and filling voids, while remainder groundmass is murky felsitic texture with patches of sericite and goethite pseudomorphing ?pyrite. No obvious phenocrysts, although some elongate patches of clear mosaic quartz could be pseudomorphs of feldspar.

Field Number	Formation:					
CP41B	Ibáñez Rhyolitoid (Altered)					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
277179	4869240					0
Final Rockname						
Devitrified and altered rhyolite lava.						

Microscopic textures (CP41B):

Sparsely porphyritic rock with faint contorted flowbanding, common recrystallised mosaic quartz, altered feldspars, remnant spherulites in a devitrified and partly recrystallised felsitic matrix.

Large feldspars are up to 3mm long, euhedral, uniformly altered to sericite pseudomorphs, occasionally invaded by patches of mosaic quartz.

Groundmass is fine pilotaxitic felsitic material, partly or wholly replaced by recrystallised mosaic quartz. Occasional partly recrystallised spherulites occur.

Too altered for QAPF.

Field Number	Formation:					
CP44	Ibáñez Rhyolitoid (Altered)					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
277552	4869633					0
Final Rockname						
Devitrified and altered spherulitic rhyolitic lava.						

Microscopic textures (CP44):

Altered and recrystallised rhyolitoid. Porphyritic with sericitised felspar phenocrysts and sparse quartz phenocrysts in a flowbanded and spherulitic groundmass with patchy recrystallisation to granoblastic quartz mosaic material.

Feldspar phenocrysts are entirely altered to fine grained sericitic material, and sometimes invaded by mosaic quartz. About 15-20%, pseudomorphs are euhedral to subhedral,sometimes broken. Often nucleation points for spherulites.

Groundmass is patchy remnant spherulitic texture, with felsitic and mosaic quartz recrystallisation along spherulite boundaries or as replacement of cores, or along flowbanding, or clear mosaic quartz in cavities. Fine grained sericite is common, also patches of hematite staining and opaque leucoxene grains after opaques.

Too altered for QAPF

Field Number	Formation:					
CP28A	Ibáñez Rhyolitoid (Altered)					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
277445	4868550					0
Final Rockname						
Propylitised flowbanded rhyolite lava.						

Microscopic textures (CP28A):

Sparsely porphyritic rock, with 5% sericitised feldspars in a recrystallised cherty/felsitic matrix with a moderate quartz LPO.

Feldspars are entirely sericitised or replaced by sericite/mosaic quartz mix. Original crystals were euhedral, glomeroporphyritic.

Matrix is mosaic quartz and remnant un-recrystallised felsitic material, with fine grained opaques. Quartz has and LPO parallel to remnant flowbanding trace, which can be seen with flow structures around phenocrysts. Occasional sericitic patches.

Oxide stains are common, mostly goethite, sourced in ?altered pyrite crystals.

Field Number	Formation:					
WI2	Ibáñez Rhyolitoid (Altered)					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
271250	4869255					0
Final Rockname						
Altered rhyolitic intrusive/cryptodome.						

Microscopic textures (WI2):

Porphyritic rock, with sparse altered sodic plagioclase and occasional quartz phenocrysts in a felsitic and partly spherulitic groundmass. Common iron oxide staining and patches of calcite.

Feldspar phenocrysts are euhedral, sometimes glomeroporphyritic, up to 5mm. RI fast and slow below medium, so probably Albite. Albite-Carlsbad twins occur. All crystals altered, murky, with patches of calcite and sericitic speckling throughout.

Quartz microphenocrysts are rare, rounded or subhedral bipyramids, up to about 0.9mm, sometimes fractured or embayed.

Groundmass is felsitic quartz and sericitised feldspar mix, with about 20–25% partly recrystallised spherulites, sometimes rimmed with hematite or goethite. Common interstitial fine grained goethite-limonite, sericite, calcite.

Rock is partly recrystallised and propylitised felsitic rhyolite.

Field Number	Formation:					
WI4	Ibáñez Rhyolitoid (Altered)					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
278590	4862260					0
Final Rockname						
Silicified spherulitic flowbanded rhyolite stock or cryptodome.						

Microscopic textures (WI4):

Sparsely porphyritic devitrified and recrystallised flowbanded rhyolite.

Feldspars, sparse, sericitised to pseudomorphs except for some partly altered microphenocrysts. Crystals were tabular or elongate laths up to 5mm, some remnants have carlsbad twins. Some have been invaded by quartz mosaic patches as well as sericite.

Flowbanding is visible as bands of grainsize variations in groundmass felsitic material, and some recrystallised spherulitic remnants. There are many veins or recrystallized mosaic quartz patches, in some cases cementing small brecciated patches. Cavities are lined with euhedral sparry/drusy quartz and filled with calcite, sometimes traces of ?celadonite — green material. Greenish patches in hand specimen are apparent as very fine grained sericitic/felsitic patches, perhaps replacement of felsitic feldspar.

Occasional opaques are amorphous haematite, sometimes with green ?celadonite disseminated around them.

Brecciation has occurred after spherulite growth, and fractures cut spherulites, flowbanding and phenocrysts.

Field Number	Formation:					
CP68 *	Ibáñez Rhyolitoid (Altered)					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
276129	4870062					0
Final Rockname						
Incipiently metamorphosed and partly recrystallised spherulitic rhyolite.						

Microscopic textures (CP68):

Devitrified and partly recrystallised spherulitic rhyolite with secondary quartz veins.

Spherulites are fairly large, irregular and partly recrystallised. Up to 8mm max. Some are nucleated on rectangular or blocky pseudomorphs composed of fine mosaic quartz, partly strained, and interstitial fine sericitic mica to the quartz. These pseudomorphs may be feldspars on which the spherulites nucleated.

Between the irregular spherulites there occurs recrystallised matrix, still felsitic in places, but now mostly murky mosaic quartz.

The entire rock is seamed with quartz and sericite mica filled cracks/veins, some of which show bearded sericite structures. Some original quartz phenocrysts appear to have been recrystallised to mosaic quartz.

QAPF not really possible.

Field Number	Formation:					
CF19B *	Ibáñez Rhyolitoid (Altered)					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
271642	4878393					0
Final Rockname						
Altered Dacitic to Rhyolitic (Caught up in margin of Cerro Farellón Granitoid.)						

Microscopic textures (CF19B):

Partly altered porphyritic rock with phenocrysts of plagioclase, altered amphibole and quartz, in a groundmass of coarse felsitic material, sometimes quite granular in texture. Overall very similar in apearance to rocks like the CF 13 dikes further southeast.

Plagioclase is rounded euhedral crystals, often zoned, partly altered. 2–5mm, about 25%. Sometimes glomeroporphyritic, with alteration along cracks and fractures near rims, or as murky partial sericitisation or clayey alteration throughout. Section Ta gives 32 at core, 15 at rim. So probably zoned Andesine to Oligoclase.

Quartz is not common as phenocrysts, 1% or less, as partially rounded, euhedral to subhedral pipyramids.

Mafic phases have ben replaced by bright green chlorite, epidote and perhaps uralite, but from elongate prismatic sections were probably an amphibole.

Groundmass is fine grained felsitic or partial mosaic quartz/feldspar material, with some degree of granular texture, varying, and altered granular green mafics, some of which still show remnant amphibole colours. Some quartz filled fractures occur.

Field Number		Formation:					
PI9A		Ibáñez Rhyolitoid (Altered)					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
283065	4859441		33	32	27	0	92
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
				8			
Other components:		Others:	Total:				
			100				
Fiual Rockname							
Silicified and recrystallised rhyodacite to rhyolite.							

Microscopic textures (PI9A):

Section cut a bit thick (yellow quartz.) Flowbauded sparsely porphyritic rock with groundmass of poikilomosaic quartz around altered feldspars, and some bands of goethite iron staining.

Large feldspars are euhedral, sometimes glomeroporphyritic, albite and carlsbad twinned, altered by sericite, calcite, and sometimes replaced by mosaic quartz and calcite/sericite mix. Synneusis twinning occurs. 2v is close to 90, so presumably oligoclase or low albite, especially if inverted from hot forms. RI looks to indicate Albite.Altered, 10–12%

Groundmass feldspars are small euhedral tablets, 0.05mm or thereabouts, 15%, seem to have simple carlsbad twinning, aud are in poikilomosaic texture in mosaic quartz developed from groundmass. Well defined flow orientation of crystals is parallel to flowbanding.

Groundmass has well developed mosaic quartz in poikilomosaic texture as above. In places there is clear mosaic quartz developed in fractures parallel to flowbanding and pilotaxitic texture. Opaques are present, up to 1mm, mostly goethite/hematite, presumably after magnetite/ilmenite. 5–8% Goethite/hematite after magnetite dissemiuated calcite.

Approximate QAPF: Plagioclase phenocrysts: 12%, Opaques:8% (but much seem secondary.) Groundmass 80% of rock, about 15% plagioclase microphenocrysts, 30–33% each of mosaic quartz and altered murky brown k-spar.

Field Number	Formation:					
CP51	Ibáñez Rhyolitoid (Altered)					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
276916	4869390					0
Final Rockname						
Altered and silicified devitrifed spherulitic rhyolite.						

Microscopic textures (CP51):

Vesicular rhyolitic rock, with fine grained altered felsitic matrix, mauy mosaic/drusy quartz filled vesicles and a trace of altered spherulites.

Groundmass is fine felsitic material, partly recrystallised into mosaic quartz and the feldspathic portion almost uniformly altered to fine platy sericitic mica between quartz grains. Some remnant spherulites are visible in this matrix.

Vesicles are filled with mosaic or drusy quartz, up to 5mm across. Some retain a central cavity, which has some goethite filling.

Common opaques are irregular patches of Goethite/limonite, some hematite and some leucoxene.

Too altered for QAPF

Field Number		Formation:					
WI5		Ibáñez Rhyolitoid (Altered)					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
278890	4862310		40	30	25	0	95
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
				5			
Other components:		Others:	Total:				
			100				
Final Rockname							
Altered flowbanded rhyolite.							

Microscopic textures (WI5):

Similar but less recrystallised rock than WI4 example of this rhyolite. Faintly flowbanded rock with strong recrystallised quartz mosaic texture in groundmass, tabular feldspars and oxidised opaques.

Feldspars are euhedral, up to 3mm, albite and carlsbad twinned, partly altered and sericitised. Plag, 20% Combined A-C method gives: 12, 20 — Oligoclase to Andesine, but bad twins. Also some K-spar — Carlsbad twinned, low RI, 2v 40–60 ish. 10% or less Probably k-feldspar. Maybe more in groundmass.

Quartz does not occur as a phenocryst phase, but is common in the groundmass.

Groundmass is both clear and murky mosaic quartz and felsitic material, with occasional feldspar microphenocrysts, which are sub-parallel to some flowlayering in a poikilomosaic texture.

Opaques and alterd mafics are 0.5mm and smaller, mostly oxidised to brownish hematite and occasional leucoxene. About 5%.

Groundmass is 75% of rock, 3–5% altered sodic plagioclase micro phenocrysts, and about 40% quartz and 20% low RI murky k-spar in felsitic and poikilomosaic material.

Field Number	Formation:					
L13	Ibáñez Rhyolitoid (Altered)					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
283720	4860910					0
Final Rockname						
Dacitic or rhyolitic lava.						

Microscopic textures (L13):

Altered rock, with remnant phenocrysts of sericitised feldspar in a groundmass of recrystallised mosaic qnartz with patches of sericite and seamed with quartz veins.

Feldspar phenocrysts are euhedral, about 10–15% of the rock, and are murky and altered, with patches and blebs of platy sericite throughout. Remnant albite twinned crystal give an angle of 16 degrees, but not enough good twins for more than one reading. RI is low, below fast and slow quartz, and also below epoxy, 2v is high, around 60–80 by optic axis figures, so most likely Albite. Many crystals are cut and partly replaced by mosaic quartz.

Groundmass is patchy and mnrky mosaic quartz, with sub-parallel grainsize variations in the mosaic picking out flowbanding. Fractures up to 1mm wide and transverse to banding, are filled with clear mosaic quartz. Sericite is widespread as platy patches and clusters or sprays within mosaic quartz, and much of the finer grainsize material is dominated by sericite. Anhedral, murky, low RI K-spar is present with the quartz mosaic, but is quite altered and difficult to identify.

Opaques are about 3%, up to 1mm, and are patchy or blobby reddish hematite or white leucoxene in reflected light.

Too altered for QAPF.

Field Number	Formation:					
WI52	Ibáñez Rhyolitoid (Altered)					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
270665	4865420					0
Final Rockname						
Altered Rhyolitic dike.						

Microscopic textures (WI52):

Altered and recrystallised rock, originally porphyritic feldspars in flowbanded matrix, but feldspars now replaced by calcite/sericite/goethite and felsitic matrix recrystallised to poikilomosaic quartz with fine disseminated sericite and some remnant microphenocrysts of feldspar in pilotaxitic texture. Also trace epidote, plus zircon.

Too altered for accurate QAPF.

Field Number	Formation:					
L3	Ibáñez Rhyolitoid (Altered)					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
287300	4861970					0
Final Rockname						
Hydrothermally altered Rhyolitic lava with Barytes vein infilling.						

Microscopic textures (L3):

Very recrystallised and altered porphyritic rock, with remnant feldspar phenocrysts entirely sericitised, and groundmass coarsely recrystallised to mosaic quartz and patchy sericite and opaques (brown hematite and white leucoxene)

Vein material is not calcite/quartz as thought in the field, but rather high RI Feldspar?, subhedral to euhedral, two good cleavages in prismatic sections, 2v Low, looks a lot like sanidine, but occurrence in vein suggests adularia K-spar of hydrothermal origin, BUT RI is very strongly above the mounting medium, so perhaps something else. RI suggests Celsian, but 2v too low. Perhaps similar Barium Feldspar (Yellow colour in hand specimen supports this.) However, could be Barytes. Some sections have cleavages that may match this, as does the straight extinction in prismatic sections. Barytes veining?

Host rhyolitoid too altered for QAPF.

Field Number	Formation:					
GA19	Ibáñez Rhyolitoid (Altered)					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
288560	4864941					0
Final Rockname						
Propylitised rhyolitic lava or dome.						

Microscopic textures (GA19):

Slightly porphyritic altered rock, with occasional calcite/sericite pseudomorphs of feldspar in a devitrified rhyolitic matrix of mosaic quartz and sericitised feldspar.

Felspars are sericitised to fine grained muscovite, with calcite patches and occasionally coarsened sericite to snbhedral platy or radial muscovite. Probably sodic plagioclase before alteration, 0.5–2mm, 5% of rock.

Specks and patches of anhedral hematite occur, about 1–2%, and also white leucoxene is present in reflected light.

Gronndmass is occasional clear qnartz, as small anhedral crystals, defining faint flowbanding or similar fabric, bnt dominated by finely intermingled mosaic quartz and altered or sericitised feldspars, with disseminated calcite as well.

Propylitised rhyolitic or dacitic lava. QAPF not possible dne to alteration and fine grainsize.

Field Nnmber	Formation:					
F3	Ibáñez Rhyolitoid (Altered)					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
288421	4865425					0
Final Rockname						
Recrystallised and silicified rhyolitic dike.						

Microscopic textures (F3):

Well recrystallised rock, with sparse feldspar phenocrysts in a recrystallised coarse matrix of poikilomosaic mosaic quartz, with quartz/calcite/goethite infill in vesicles.

Feldspar phenocrysts are present in two populations, 0.5–3mm euhedral and partly altered albite phenocrysts, and smaller enhedral feldspar microphenocrysts (also appear to be albite.) in poikilomosaic texture in the recrystallised groundmass quartz mosaic. Some albite crystals appear to have grown overgrowths during the matrix recrystallisation.

Quartz is present as veins, mosaic quartz dominates the groundmass, and also as clear crystalline drusy quartz lining vesicles and cavities. Cavities also include calcite, goethite, etc.

Secondary muscovite occurs, in platy irregular patches. This could either be low grade metamorphism material, coarsened up from sericite, or an alteration of biotite.

Groundmass is dominated by coarse quartz mosaic, but patches of felsitic groundmass remain, with feldspar microphenocrysts defining slight flow orientation. Opaques are altered to lencoxene or goethite/hematite.

Too altered for accurate QAPF. No phenocryst quartz, so maybe more dacitic-rhyodacitic than rhyolitic.

Field Number	Formation:					
F8A	Ibáñez Rhyolitoid (Altered)					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
287390	4869125					0
Final Rockname						
Altered Rhyolitic Lava Flowfront Breccia.						

Microscopic textures (F8A):

Porphyritic rock (Cut from breccia block) with phenocrysts of feldspar, quartz and biotite in a fine grained or aphanitic felsitic matrix. Some faint flowbanding texture in matrix, partly recrystallised to mosaic quartz in places, and many patches of secondary calcite, especially around phenocrysts.

Quartz is rounded, embayed bipyramids, up to 2mm. Some crystals have inclusions of biotite. Some have slight overgrowth of mosaic quartz from recrystallised felsitic groundmass.

Feldspars are euhedral to subhedral sodic plagioclase, with albite and carlsbad twins, some pericline twinning. Some have little tabular overgrowths at edges, of small albite twinned crystals in groundmass, in semi or full optical continuity. RI of large albite twinned crystals has fast and slow distinctly below medium. 2v about 80 ish, so albite if this feldspar has re-crystallised somewhat at low temps.

Biotite is irregular, damaged crystals, pleochroic dark brown. Individual crystals show cleavage fragments levered apart from the body of the crystal by quartz mosaic from the recrystallised groundmass that has invaded between cleavage layers. Some crystals also appear to have broken along cleavage during flow of the lava.

Groundmass is partly recrystallised felsitic material, to quartz mosaic and carlsbad twinned k-spar microphenocrysts, also some sodic plagioclase microphenocrysts, with some replacement by calcite in irregular patches. Green granular mineral occurrs in groundmass, not chlorite, maybe pyribole of some sort.

Field Number	Formation:					
WI120 *	Ibáñez Rhyolitoid (Altered)					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
271695	4862680					0
Final Rockname						
Flowbanded rhyolitic cryptodome or lava.						

Microscopic textures (WI120):

Very well recrystallised rhyolitic rock. Sparse rounded bipyramidal quartz occur, with well developed rims from recrystallised groundmass quartz mosaic. Feldspars are altered to sericite.

Quartz phenocrysts are about 5%, euhedral, rounded, with wide rims about 1/4 their original width, overgrown onto them during devitrification/recrystallisation of groundmass. Rims are murky, but optically continuous with original phenocrysts.

Feldspars are trace only, entirely replaced by sericite.

Groundmass is recrystallised to mosaic quartz, and about 30% sericitic or cherty altered feldspar, and about 1% hematite/goethite. Some lithophysae occur, lined with hematite/goethite.

QAPF not feasible.

Field Number	Formation:					
PI96	Ibáñez Rhyolitoid (Altered, ?Rheomorphic tuff?)					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
276013	4872096					0
Final Rockname						
Either well welded and partly reomorphic crystal poor tuff or partly vesiculated rhyolitoid lava.						

Microscopic textures (PI96):

Thin section is cut a bit wedge shaped. Rock is very even grained, with faint stratification defined by remnant? Glass shard texture. Feldspars are entirely altered to sericite, glass is recrystallised to quartz mosaic and felsitic material in matrix.

Quartz is euhedral, rounded and embayed, occasionally fractured. Up to 2mm, less than 5% as phenocrysts.

Feldspars are euhedral or anhedral, entirely altered to sericitic pseudomorphs, originally up to 2–3mm crystals, less than 5% of rock.

Groundmass is partly mosaic recrystallised felsitic material and what looks like recrystallised glass shards, but may be partly flattened vesicles infilled with mosaic quartz, as some patches, although showing shard like shape, have core of sericite and lining of euhedral spiky quartz around edge.

Too altered for QAPF.

A.2.3 Basaltic and Basaltic Andesitic Extrusive Rocks

Field Number		Formation:					
CP73B		Ibáñez Andesitoid					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
275400	4869600		2	1	75	0	78
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
14				5			3
Other components:		Others:	Total:				
			100				
Final Rockname							
Olivine Basalt lava breccia.							

Microscopic textures (CP73B):

Partially altered basaltic to andesitic rock with pilotaxitic altered plagioclase with blocky intergranular pyroxene phenocrysts. Plagioclase and pyroxene phenocrysts are up to 1–2mm, in a pilotaxitic and intergranular groundmass of sub 0.4mm to 0.1mm plagioclase, pyroxene, chloritised olivine and pyroxene, secondary carbonates, iron oxides after opaques, and minor interstitial quartz.

ML on groundmass pilotaxitic microphenocrysts: 16, 33.5, 18, 8, 30, 33.5 gives about An 52%, just into Labradorite, while Carlsbad Albite twinning gives 8,30, about An 45%. Many phenocrysts show patchy sericitisation and replacement by patches of K-spar.

Pyroxene is Augite group, up to 0.026 birefringence, often chloritised, 2v small to moderate (25–30). Subhedral, granular crystals up to 0.5mm in groundmass, but generally less, and occasional large phenocrysts up to 1–2mm, mostly chloritised. Augite to subcalcic augite.

Opaques are blocky oxidised magnetite, about 3–5%.

Chlorite occurs as patches interstitial to plagioclase, but also as larger pseudomorphs of Olivine with red brown altered iddingsite cores.

Groundmass also has patches of ?siderite or similar carbonate.

Estimated QAPF: Plag:75%, Kspar 1% or less Opaques 5%, Pyroxene 14%, Olivine 3%, Quartz 2%.

Field Number	Formation:					
PI27A	Ibáñez Andesitoid					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
274000	4872050					0
Final Rockuame						
altered basaltic andesitic scoria.						

Microscopic textures (PI27A):

Altered and oxidised andesitic scoria, with pebble through to cobble size clasts of oxidised, altered hematite/goethite rich vesicular porphyritic andesitoid. Voids are filled with mosaic quartz, and patches of clasts are altered to quartz mosaic, anhedral feldspar and granular epidote.

Most of clasts are altered to opaque hematite/goethite/clay mix, but many have remnant swallowtail plagioclase in groundmass and partly altered large euhedral phenocrysts of zoned or sieve textured plagioclase.

Field Number		Formation:					
F28 *		Ibáñez Andesitoid					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
287250	4871405		2	10	55	0	67
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
20	1			9			
Other components:		Others:	Total:				
Calcite		3	100				
Final Rockname							
Basaltic Andesite.							

Microscopic textures (F28):

Porphyritic rock with phenocrysts of plagioclase, altered pyroxene and magnetite in a pilotaxitic groundmass of plagioclase laths with intergranular magnetite and altered pyroxenes, and occasionally some intersertal anhedral k-spar or quartz? Secondary alteration includes calcite and sericitic replacement of fledspars, carbonates and chlorite as replacement of mafics and as vein and void filling material, plus hematite replacment of mafics and opaques and as stains on other minerals.

Plagioclase phenocrysts are euhedral to subhedral crystals, occasionally sieve textured or rimmed, 0.25–4mm, 25%. Crystals are moderately altered, with sericite and calcite replacing some cores, while others have patchy alteration to Albite or k-spar along cleavage planes. Zoned crystals are often altered to sericite, chlorite and calcite in calcic cores. ML on unaltered crystal cores: 29, 32, 40.5, 33, 28, 33, 28, so about An 68%. Most crystals have a single outer rim overgrown on a dissolution surface, of about 15 degrees less in extinction angle than the cores, about An35%, so simple normal zoning from Calcic Labradorite to Sodic Andesine.

Pyroxene phenocrysts are relict only, 0.5–2mm, up to 5%, replaced by green uralitic amphibole or chlorite and calcite. Some also replaced by hematite and high releif carbonates (Mg or Fe cabonates.) Remnants of unaltered phenocrysts show 90 degree cleavages, and altered crystals retain octagonal pyroxene end sections as pseudomorphs. 2v of remnant patches is small to moderate (25–30) suggesting subcalcic Augite, but some crystal remnants have -ve 2v also about 30, suggesting some orthopyroxene is present (Trace to 1%).

Groundmass is pilotaxitic sodic plagioclase and intergranular altered pyroxenes and opaques, about 30% plag, 9% oxidised opaques, 15% altered pyroxenes, Some silica, uniaxial negative so probably Cristobalite, about 2% and low RI anhedral K-spar interstitial to all, maybe 10%.

Field Number		Formation:					
WI99 *		Ibáñez Andesitoid					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
273720	4863380		5	0	60	0	65
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
13				10			12
Other components:		Others:	Total:				
			100				
Final Rockname							
Partly altered Olivine Basalt lava.							

Microscopic textures (WI99):

Fairly equigranular rock, dominated by strong pilotaxitic feldspar orientation. Some larger feldspar phenocrysts have cores altered to coarse muscovite, presumably from mild reheating of this rock by WI98 intrusive recrystallising sericitised cores. Mafic minerals have been entirely altered to reddish hematite and cherty material. The hematite in some of these pseudomorphs preserves a cleavage structure, and from the shape they were presumably a pyroxene, probably cpx.

Matrix feldspars are strongly pilotaxitic euhedral laths in intergranular texture with altered mafics and opaques. From RI, matrix feldspars appear to be Oligoclase, (Fast equal or just below medium, Slow just above it, if medium is 1.54). Albite-Carlsbad reading on G/mass feldspar: 35.5 & 25.5, = An68%, Labradorite, so rock is approx 60% sub 1mm labradorite. Maybe range to oligoclase.

Remainder of matrix is fine granular partly altered clinopyroxene and opaques, in intergranular texture with plagioclase. Altered mafics, possibly olivine but now hematite or iddingsite. Minor quartz occurs as anhedral patches between opaques and plagioclase microphenocrysts, less than 5%.

Large 1–2mm blocky or lozengy double pointed reddish to opaque pseudomorphs could be iddingsitised or hematite replaced Olivines. Otherwise,the hematite in some of these pseudomorphs preserves a cleavage structure, and from the shape they were either olivine or pxne.

Approx QAPF: Plag:60%, Altered Olivine/pxne 15%, groundmass Opaques: 10%, Quartz 5% or less, groundmass pyroxene 10%.

Field Number	Formation:
CP24A *	Ibáñez Andesitoid

Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
277848	4868650	0	0	60		60

Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
			15	5			

Other components:	Others:	Total:
Calcite	20	100

Final Rockname
Altered Basalt Lava from Labradorite phenocrysts. TAS plots as Trachybasalt, so possibly sodium enriched during metasomatism/thermal metamorphism.

Microscopic textures (CP24A):

Aphanitic rock dominated by fine grained feldspars in pilotaxitic texture, partly altered and replaced by calcite, with sparse clinopyroxenes altered to uralite or green chlorite. Chlorite also common as alteration in groundmass mafics. Calcite patches and veins ubiquitous.

Rock is 60–65% feldspar microphenocrysts, euhedral laths, with strong pilotaxitic flow orientation, and intergranular material now altered to chlorite, iron oxides, clays. ML on feldspars: 33, 24, 23, 28, 29, 17 = An% 50 or greater. Labradorite. Some sericitisation of groundmass feldspars, also some replacement of cores. Zoning sparse, only on bigger microphenocrysts, slightly more calcic in cores. Due to alteration of groundmass, no way to spot any primary k-spar. (note, 14% normative orthoclase, though.)

Disseminated secondary calcite common thoroughout, about 20% of rock.

Opaques are blocky, look fairly un-altered. Maybe primary Magnetite or secondary pyrite. 3–5%

Chlorite is disseminated throughout rock, as small blocky or rectangular pseudomorphs of pyroxene. Some fibrous material may be uralite. About 15%.

Field Number	Formation:
WI86B	Ibáñez Andesitoid

Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
272060	4864280					0

Final Rockname
Altered basaltic lava breccia.

Microscopic textures (WI86B):

Calcite cemented breccia, originally lava flow top breccia. Clasts are angular, poorly sorted cobble to boulder in hand specimen, down to pebble through to coarse sand in thin section, clast supported. Very oxidised, presume baked by overlying lava. Calcite replaces most feldspars and forms a sparry cement between clasts. Clasts are otherwise altered to opaques, hematite, clays.

Clasts are vesicular angular andesitic rock, with altered pilotaxitic feldspar microphenocrysts, up to 0.3 or 0.4mm, now calcite or sericite, euhedral laths with some swallowtail ends, with intergranular opaque iron oxides after mafic minerals, presumably pyroxene and magnetite.

Voids and vesicles are filled with anhedral sparry calcite and some orange iron oxide staining.

Field Number	Formation:
WI86A *	Ibáñez Andesitoid

Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
272060	4864280	2	0	70	0	72

Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
10			5	8			

Other components:	Others:	Total:
Calcite	5	100

Final Rockname
Partly altered Olivine Basalt with iddingsitised olivines.

Microscopic textures (WI86A):

Porphyritic rock with well developed pilotaxitic texture in groundmass feldspars, and altered olivines now replaced by ? Iddingsite or hematite.

Large pseudomorphs show dark red brown alteration product on rims, invading cores along heavy, olivine like fractures. Cores are either replaced by the same material, or by chlorite and cherty material, possibly quartz. Crystal shape is indicative of subhedral olivine, and some are glomeroporphyritic. About 3–5%,, 1–2mm, some pseudomorphs up to 5mm.

Groundmass is well developed pilotaxitic texture of plagioclase feldspars with intergranular mafics, some alteration patches and oxide patches. Mafics are partly altered sub 0.3mm granular subhedral c-pyroxenes. Groundmass approximately 3–8% opaques (oxidised magnetite), 10% partly altered granular clinopyroxene, 5–10% disseminated interstitial calcite and pale green chlorite as alteration products, maybe 1–2% interstitial quartz, remaining material is plagioclase laths, about 65–70%.

Groundmass plagioclase is generally unaltered, euhedral albite and carlsbad twinned plagioclase laths, between 0.1–0.4mm, with strong flow orientation. ML gives: 27, 30, 26.5, 33.5, 35, 20, 25 = An%58, Labradorite.

Field Number		Formation:					
LN3E		Ibáñez Andesitoid					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
278818	5006164		1	1	53	0	55
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
20				25			
Other components:		Others:	Total:				
			100				
Final Rockname							
Basaltic or Basaltic andesitic Lava.							

Microscopic textures (LN3E):

Fine grained volcanic rock with occasional partially altered small (sub 1mm) euhedral plagioclase phenocrysts in a pilotaxitic groundmass of fine plagioclase laths with intergranular altered mafics and oxidised opaques. Alteration includes sericite, chlorite, iron oxides and patchy calcite.

Plagioclase phenocrysts are occasionally sieve textured, generally euhedral, about 1–3%, sub 1mm. Too altered for ML. Groundmass plagioclase is about 50% of rock, fine grained sub 0.2mm plagioclase laths in pilotaxitic texture with intergranular opaques and partially oxidised clinopyroxenes. Albite-Carlsbad on g/mass plag: 15, 35, about An 60%, Labradorite.

Pyroxenes are mainly present in the groundmass, about 0.1mm or less, although ocasional 0.5–1mm larger phenocrysts occur. Some crystals are unaltered flesh toned clinopyroxene, whereas most are partly oxidised, chloritised or uralitised. Probably about 15–20% before alteration.

Opaques are common, oxidised magnetite and secondary hematite after altered pyroxenes and mafics. About 25%.

Trace anhedral quartz or other silica polymorph in groundmass, 1% or less, difficult to tell if any k-spar present.

Field Nnmber	Formation:					
WI83A	Ibáñez Andesitoid					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
272280	4863180					0
Final Rockname						
Albite-Epidote facies hornfels (Olivine Basalt.)						

Microscopic textures (WI83A):

Altered porphyritic volcanic rock, with chlorite and epidote pseudomorphing abont 20–25% 1–2mm phenocrysts, with blocky and lozenge shapes, in a groundmass of pilotaxitic altered feldspar laths with intergranular mafics altered to chlorite and epidote, with common secondary calcite and ?siderite.

Groundmass laths were plagioclase, but are now sericitised and replaced with calcite, and have RI moderately below epoxy, indicating albitisation. Some feldspars replaced with epidote.

Mafic phenocrysts are subhedral and euhedral phenocrysts up to 2mm, and are replaced entirely by pale green chlorite, epidote, opaque hematite and calcite, plus some siderite. There are two populations, one blocky and square or octagonal, and one lozenge shaped, with some skeletal crystals. Probably Clinopyroxene and Olivine before alteration.

Minor levels of fibrous amphibole may occur in groundmass.

Secondary calcite is common.

Albite-Epidote facies hornfelsed basalt , probably olivine basalt similar to those of the remainder of El Maiten hill.

Field Number		Formation:					
WI82B *		Ibáñez Andesitoid					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
272004	4863160		0	1	60	0	61
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
5				30			4
Other components:		Others:	Total:				
			100				
Final Rockname							
Altered Olivine Basalt.							

Microscopic textures (WI82B):

Altered porphyritic volcanic rock, with 5% altered mafic phenocrysts in a pilotaxitic groundmass of feldspar laths and fine grained mafics, altered by patches and veins of calcite.

Altered mafic phenocrysts are up to 2mm, with white leucoxene, hematite and calcite forming pseudomorphs of clinopyroxene and perhaps olivine.

Groundmass is euhedral-subhedral 0.1–0.3 feldspar laths, plagioclase, with intergranular altered mafics, opaques, and secondary chlorite and calcite. ML on plagioclase gives: 14, 21, 31.5, 20, 29, 27, 18. = An% 45 — Andesine

Groundmass has fine interstitial chlorite and occasional quartz between the feldspars. Calcite rims opaque pseudomorphs and forms anastomosing veins through the rock.

Pseudomorphs of Olivine/pyroxene make this rock probably an altered Olivine Basalt rather than andesite. Feldspars are albitised/calcium depleted. Calcium is definitely mobile.

Approx 20–30% altered mafics and opaques, in 60–70% fine pilotaxitic plagioclase, maybe trace Kspar in groundmass.

Field Number	Formation:					
CP29A	Ibáñez Andesitoid					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
277264	4868350					0
Final Rockname						
Volcaniclastic or pyroclastic andesitic breccia or lithic tuff.						

Microscopic textures (CP29A):

Irregular to rounded clasts of pilotaxitic andesitoid clasts occur in a fine, felsitic matrix including plagioclase crystals, fractured quartz and finely cominnuted rock fragments. Calcite is ubiqitous as small patches throughout the groundmass. Chlorite is a common alteration product and may be acting as a cement.

Field Number		Formation:					
PI17B		Ibáñez Andesitoid (Altered)					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
274225	4870845		0	10	60	0	70
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
20				5			5
Other components:		Others:	Total:				
			100				
Final Rockname							
Olivine Basalt, hornfelsed to Albite-Epidote facies by nearby granitoids.							

Microscopic textures (PI17B):

Porphyritic rock with phenocrysts of plagioclase and pyroxene in a pilotaxitic groundmass of felspar laths and intergranular mafics and opaques. Alteration consists of secondary quartz, white chalcedony/chert and green chlorite as vesicle filling, and larger plagioclase phenocrysts have cores altered to patchy sericite and clusters or sprays of green epidote, sometimes patches of green chlorite.

Large feldspar phenocrysts are euhedral to subhedral, sometimes glomeroporphyritic with pyroxene. Up to 4mm, 10%. Alteration is epidote/sericite/calcite chlorite, mainly confined to the cores, indicating saussuritisation. RI is difficult to measure, with few grains near margins of slide, and none have good sections for extinction angle work. RI has slow about equal or slightly above epoxy, fast just below, so probably Albite or Sodic oligoclase, but posibly albitised due to saussuritisation and growth of epidote.

Pyroxene phenocrysts are euhedral to slightly rounded, up to 2mm, 5%, usually simple, but sometimes twinned or glomeroporphyritic with clusters of altered plagioclase and opaque pseudomorphs of something else. 2v small to moderate, so Augite or subcalcic augite. Mostly unaltered. Large clusters with cpx, saussuritised plagioclase and opaque may be cognate xenoliths from magma chamber, as have cumulate type textures.

Large, up to 3mm,3–5%, opaque to dark brown pseudomorphs with some chlorite are probably iddingsite after olivine. Some look like olivine 001 sections.

Groundmass is feldspar laths (50%) and intergranular opaques (5%) and clinopyroxenes (15%), with about 10% subhedral or anhedral murky low RI K-spar interstitial to plagioclase laths. Feldspars are generally unaltered, although some are sericitised in places. ML: 21, 24, 28, 27, 28.5, 26, = An% 43 ish, andesine or greater.

Field Number	Formation:					
CP70	Ibáñez Andesitoid (Altered)					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
275870	4869725					0
Final Rockname						
Hydrothermally altered and chloritised Andesitic Lava.						

Microscopic textures (CP70):

Altered porphyritic volcauic rock. Sparse feldspars are altered to calcite and sericite, while mafic phenocrysts are altered to opaque hematite, presumably after pyroxene.

Groundmass has faint remnant feldspars in pilotaxitic and intergranular textures, but now recrystallised and altered to sericitic muscovite, calcite, chlorite, etc.

Fractures and vesicles are lined with fibrous chlorite and filled with sparry calcite. Any original phenocrysts are replaced by pseudomorphs of hematite and opaques for mafics and calcite/chlorite/sericite mix for feldspars.

Liesegang bands of iron oxides form the reddish streaks seen in hand specimen, visible as disseminated red brown hematite in thin section. Entirely altered Andesitic to dacitic lava, QAPF not really possible.

Field Number	Formation:					
CP65	Ibáñez Andesitoid (Altered)					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
274848	4871900					0
Final Rockname						
Calcite cemented basaltic or basaltic andesitic lava breccia/scoria.						

Microscopic textures (CP65):

Pyroclastic rock with granule through to gravel size clasts of altered and oxidised vesicular angular andesitic clasts, clast supported, with sparry calcite void filling.

Clasts are porphyritic and range from vesicular andesitic rocks with sparse pilotaxitic plagioclase in an opaque oxidised matrix with hematite staining, to fractured dense andesitoids and dacitoids without vesicles, porphyritic with sodic plagioclase, zoned and sieve textured, in a pilotaxitic groundmass of feldspar laths with intergranular opaques, occasional quartz and oxidised mafics.

Feldspars are partly sericitised plagioclase, looks like andesine from some remnant twins, but RI of many crystals is well below epoxy, so probably albitised. Dacitic clasts may have groundmass K-spar, and some have minor groundmass quartz.

Mafics are altered to opaque hematite, or perhaps chlorite in some clasts. Vesicles and inter-clast voids are filled by clear, sparry calcite. Some clasts have quartzite zenoliths. Minor quartz occurs as lining of void spaces and rims on some clasts.

Field Number	Formation:					
PI74	Ibáñez Andesitoid (Altered)					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
273155	4871940					0
Final Rockname						
Altered Basaltic Andesitic Lava.						

Microscopic textures (PI74):

Fine grained feldspathic volcanic rock, with partly recrystallised feldspar lath groundmass, chloritised or uralitised mafics, sericite and calcite replaced feldspars, common goethite or hematite replacing mafics and opaques. Veins with some quartz, calcite and epidote occur.

Large feldspars were subhedral, glomeroporphyritic, probably plagioclase, now sericitised, replaced by calcite, sericite, epidote and also goethite hematite staining common on pseudomorphs.

Groundmass feldspars are partly recrystallised laths, with well developed pilotaxitic texture, but often recrystallised to patchy felsitic or mosaic feldspar and perhaps some quartz. RI is strongly below medium, so probably albite.

Mafics are oxidised to red hematite and opaques, although some blocky square phenocrysts are altered to pale green chlorite. Opaque pseudomorphs may be after olivine, chlorite after clinopyroxene.

Remainder of g/mass is chloritised mafics, sparse veins with quartz/calcite/epidote, oxidised opaques, etc. This rock probably too altered for chemistry.

Field Number	Formation:					
WI86C *	Ibáñez Andesitoid (Altered)					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
272060	4864280					0
Final Rockname						
Altered Olivine Basaltic Lava.						

Microscopic textures (WI86C):

Fine grained porphyritic rock with altered, oxidised pseudomorphs of Olivine and Pyroxene in a matrix of euhedral feldspar laths in intergranular texture with opaques, oxidised fine mafics and secondary calcite. Veins of calcite and pale green chlorite occur, some with ?zeolite or adularia. Some vesicles are filled with green chlorite, with blue interference colour. Quartz ?trace as vein?

Large brownish red pseudomorphs occur, up to 2mm. Some are blocky, rectangular tablets, others are lozenge or diamond shaped. Cores may be chlorite or calcite seamed with red-brown material coming in from the rim, but many crystals are entirely of the brown material. From the crystal shape and alteration, most of these pseudomorphs appear to be iddingsite/hematite/chlorite after Olivine, but some may have been pyroxene, particularly the square or blocky ones. 3–5%

Groundmass is euhedral to subhedral partly altered plagioclase laths, .2mm or less, in intergranular texture with altered, minor mosaic quartz and oxidised mafics and common secondary calcite, plates of chlorite, patches of hematite, etc. Cores of many crystals altered, but ML on good twins is: 29, 27, 23, 24, 30, 34, 34.5, = An%55–58, Labradorite, groundmass 0.2–0.4mm and less, 60%

Too altered for QAPF, although plagioclase is about 60% of rock.

Field Number	Formation:					
CF23B	Ibáñez Andesitoid (Altered)					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
272273	4876633					0
Final Rockname						
Mineralised Olivine Basalt.						

Microscopic textures (CF23B):

Chaotic aggregate of radial clusters of chlorite, granular epidote, quartz mosaic, patches of bladed hematite and occasional remnant pilotaxitic volcanic textures, as ghost texture within chlorite. Chlorite and opaque minerals form pseudomorphs of lozenge shaped Olivine phenocrysts, while groundmass is altered pilotaxitic feldspars, altered mafics and opaques.

Reflected light reveals sparse mineralisation, occasional massive, anhedral pyrite, with rims or blebs of chalcopyrite. Disseminated chalcopyrite and pyrite occur in groundmass. Larger chalcopyrite has intricate careous weathering and rims of covellite, ?chalcocite and perhaps sphalerite.

Field Number	Formation:					
PI101	Ibáñez Andesitoid (Altered)					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
275460	4872416	10	75	15		100
Final Rockname						
Albite-Epidote facies hornfels (basaltic andesitic lapilli tuff.)						

Microscopic textures (PI101):

Contact metamorphosed lithic lapilli tuff, with irregular or granular sub angular juvenile clasts of pilotaxitic andesitoid/dacitoid, clast supported, and occasional spherulitic or poikilomosaic rhyolitic clasts and quartz/sodic plagioclase crystal fragments, with minor felsitic devitrified matrix, and calcite, mosaic quartz, epidote void filling and porphyroblasts of epidote within clasts. Also patches of green fibrous chlorite common throughout.

About 70% altered andesitoid lithics, 5 % rhyolitoid lithics, 10% rhyolitoid crystal fragments and 15% devitrified felsitic matrix and secondary void filling.

Field Number	Formation:					
PI26A	Ibáñez Andesitoid (Altered)					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
273780	4872175					0
Final Rockname						
Albite Epidote facies Hornfels. (Basaltic Andesitic Lava.)						

Microscopic textures (PI26A):

Altered rock, originally sparsely porphyritic with feldspars and ?clinopyroxene in pilotaxitic feldspar matrix. Matrix is now partly recrystallised and mafics are pseudomorphed by chlorite and uralite. Oxidised patches and veins of hematite/goethite are common, as are veins of epidote with wide alteration halos. Disseminated crystals of epidote are also growing in the matrix. Later fractures crosscut epidote and oxide veins and are still open, but with some drusy quartz growth on vein edges.

Groundmass feldspar is murky, altered and partly recrystallised to anhedral low 2v albite and some quartz or altered to clay/sericite and epidote. Remaining crystals give RI below medium, probably albite or albitised.

Large blocky mafics appear to be oxidised pyrite cubes, also indicative of altered state.

Field Number	Formation:					
WI102	Ibáñez Andesitoid (Altered)					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
272440	4862920					0
Final Rockname						
Hornfels (Olivine Basaltic lava Breccia.)						

Microscopic textures (WI102):

Vesicular rock with groundmass of strongly pilotaxitic altered sodic plagioclase, now sericitised or calcitised, or recrystallised into ?rough quartz mosaic.

Pilotaxitic rock with altered sodic plagioclase in felted texture, partly sericitised and also partly poikilomosaic with secondary quartz. Microphenocrysts are up to 0.2–0.3mm, with sericitised cores and replacement by platy sericite and calcite common.

Mafic phases are replaced by opaque iron oxides and perhaps pyrite, also calcite, and from blocky shapes and lozenges are pseudomorphs of primary pyroxene and olivine.

Vesicles are large, up to 5mm, lined with granular yellow green epidote and filled with calcite, mosaic and dogstooth quartz, chlorite, and opaques. Pyrite cubes are common, although beginning to oxidise.

Hydrothermally altered and hornfelsed Olivine basaltic lava Breccia.

Field Number		Formation:					
WI29		Ibáñez Andesitoid (Altered)					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
270760	4859040			8	55		63
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
17				20			
Other components:		Others:	Total:				
			100				
Final Rockname							
Altered Basaltic Andesite Lava.							

Microscopic textures (WI29):

Porphryitic and vesicular volcanic rock, with common altered plagioclase phenocrysts in an altered groundmass of plagioclase and oxidised opaques and mafics. Common secondary chlorite as vesicile and vein filling, and as alteration of mafics.

Phenocryst plagioclase is about 30–35% of rock, euhedral to subhedral, often glomeroporphyritic, 0.5–4mm. Murky and brown in ppl, with common sericitic alteration or patches of chlorite in voids. Too altered for extinction angle methods, but RI fast and slow are well below epoxy, so Albite or albitised.

Groundmass plagioclase is similarly altered, and is in pilotaxitic to intergranular textures with interstitial opaques and oxidised or chloritised mafics. Anhedral material interstital to plagioclase microphenocrysts is very murky, but has low RI, so perhaps K-spar 5–8%.

Main mafic phenocryst was pyroxene, now chlorite pseudomorphs with occasional octagonal end sections visible.

Overall about 55% plag, 17% chloritised ?pxne, 15% opaques and secondary hematite, (also vesicles are about ,10% chlorite filled void space.)

Field Number	Formation:					
WI103B	Ibáñez Andesitoid (Altered)					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
272570	4863280					0
Final Rockname						
Hornfels. Basaltic rock in contact with chilled and altered minor intrusive margin.						

Microscopic textures (WI103B):

Very altered rock. Small remnant of andesitoid in corner of thin section is fine grained, aphanitic with small (1mm or less) altered sodic plagioclase in a matrix of altered feldspars, secondary quartz and oxidised mafics with patches of chlorite and secondary epidote. Bulk of thin section is fine serrated boundary mosaic/felsitic textured to hypidiomorphic quartz and feldspar studded with clusters of large 1–2mm epidote crystals, chlorite pseudomorphs of ?hornblende, and a lot of secondary calcite.

Hornfelsed andesitoid in contact with chilled and altered minor intrusive margin.

Field Number		Formation:					
GA10B *		Ibáñez Andesitoid (Altered)					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
273720	4863380		0	5	70	0	75
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
5				15			
Other components:		Others:	Total:				
Calcite		5	100				
Final Rockname							
Altered Basaltic Andesitic Lava.							

Microscopic textures (GA10B):

Rock is porphyritic, with plagioclase phenocrysts up to 3mm, euhedral, in a matrix of pilotaxitic plagioclase microphenocrysts and opaque minerals, perhaps some glass. Alteration is common, with some sericitisation of plagioclase and occurrence of calcite within vesicles and some veins or small patches in the groundmass. Pyroxene has been replaced by pseudomorphs of calcite and ?haematite.

Plagioclase phenocrysts are euhedral to subhedral crystals, from microphenocrysts in the groundmass (sub 0.1mm) to 2 or 3mm phenocrysts. Some crystals have slight zoning, some have altered cores and sieve texture, but most do not. Alteration is either patchy sericite, patchy calcitised cores, or just murky ?clay. Albite-Carlsbad twinning gives: 5, 15, about An26%, while ML gives 7, 11, 15, 6, 5, 16, 15.5, about 5 or 20% An. RI has fast strongly below medium, slow just below medium. — Albite or albitised.

Mafics are blocky crystals now pseudomorphed by calcite and hematite/goethite. Presume they were Clinopyroxene from blocky, square cross-sections.

Groundmass is sodic plagioclase microphenocrysts, in intergranular texture with altered mafics and opaques (now hematite and remnant magnetite, and some dark brown altered glass.) Vesicles are filled with calcite, and occasional drusy quartz.

About 35% plagioclase phenocrysts, 5% oxidised mafics, 60% groundmass of about 35% plagioclase microphenocrysts, 15% opaques, 5–10% low RI anhedral k-spar.

Field Number		Formation:					
F38 *		Ibáñez Andesitoid (Altered)					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
284425	4869125		1	5	65	0	71
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
			10	9			
Other components:		Others:	Total:				
Calcite		10	100				
Final Rockname							
Altered Basaltic Andesitic vent breccia. Chem gives trachy andesite, but really not trustworthy due to alteration.							

Microscopic textures (F38):

Thin section may be cut a little thick. Fragmental rock of andesitoid rock fragments, with andesitoid clasts in fine grained matrix of crystals and andesitoid fragments. Very altered, with ubiquitous calcite as replacement of feldspars, void filling and veining. Opaque and dark brown iron oxides are common as oxidation/alteration of mafics and groundmass of clasts.

Clasts are andesitoid, with phenocrysts of euhedral plagioclase, in altered groundmass with disseminated iron oxides. Oxides also rim clasts and crystals. Some remnant pyroxene and Olivine, but some clasts have chlorite/opaque pseudomorphs with amphibole shapes instead. Vesicles are filled with chlorite or calcite.

Clasts are about 30% sericitised and clayey plagioclase, up to 10% each chloritised and oxidised mafics (to opaque iron oxides) Groundmass is mainly fine grained altered feldspars, about 55–60% of rock probably about 35% plag, remainder fine grained oxidised mafics and opaques, with common secondary chlorite and calcite. Trace quartz, probably secondary.

Field Number	Formation:					
WI96E	Ibáñez Andesitoid (Hornfelsed)					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
272580	4863880					0
Final Rockname						
Hornblende hornfels (Olivine Basalt)						

Microscopic textures (WI96E):

Fine grained aphanitic volcanic rock, with remnants of pilotaxitic texture and oxidised mafic phenocrysts, spotted with granular clusters of epidote and pale green hornblende. Calcite and epidote occur as secondary void filling.

Original texture/mineralogy was pilotaxitic feldspar laths with intergranular opaques (magnetite) and mafics (probably clinopyroxene, and opaque/chlorite/calcite pseudomorphs are blocky and lozenge shapes, probably altered olivine and pyroxene phenocrysts).

Feldspar laths are still visible, but are sericitised and replaced by calcite, and now have RI well below epoxy, so are probably albitised plagioclase. Mafic phase is replaced by pale green pleochroic actinolitic hornblende, often granular or fibrous. Actinolitic amphibole also occurs as lining of void spaces with fill of calcite and epidote.

Calcite is common as alteration of feldspars, also as retrograde rims on actinolitic amphibole.

Original grainsizes retained, witth feldspars about 0.1–0.2mm, larger mafic pseudomorphs up to 0.5mm, and granular amphibole replacing mafics about 0.1–0.2mm.

Hornblende-hornfelse facies contact metamorphosed Olivine basalt or basaltic andesite.

Field Number		Formation:					
CP18A *		Ibáñez Andesitoid (Hornfelsed)					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
278225	4869590		0	15	55	0	70
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
			25	5			
Other components:		Others:	Total:				
			100				
Final Rockname							
Albite-epidote facies hornfels. (Olivine basaltic lava.) Chemistry is tephritic, but as other Ibáñez lavas plot as basalt-basaltic andesite this is probably an altered example.							

Microscopic textures (CP18A):

Aphanitic rock, with slightly pilotaxitic but mostly intergranular textured feldspars, opaques and 10–15 % up to 1mm chloritised mafics. Some patches or void fill of calcite.

Feldspars are fine grained, 0.4mm or less, euhedral laths, with altered sericitised cores, some crystals are albitised from original composition as RI now below epoxy, but others still show RI strongly above epoxy, so at least Calcic Oligoclase. Dominating texture is slightly pilotaxitic feldspar laths with intergranular altered mafics and opaques. Laths show swallowtail or stepped ends indicating slight undercooling on crystallisation.

Mafics are altered to dull green pleochroic amorphous or platy length slow chlorite and some leucoxene, and both 0.4–1mm phenocryst sizes and fine matrix microphenocrysts are altered to this chlorite/opaque mix. Larger pseudomorphs are either lozenge shaped after olivine, or blocky and square after pyroxenes.

Chlorite also occurs as void filling material with calcite.

Some cherty recrystallisation of groundmass material occurs, and patches of low birefringence moderate RI biaxial material possibly K-spar, but also some euhedral pseudomorphs of old phenocrysts so may be albitised plagioclase.

Some clusters of secondary epidote, indicating that this rock may be hornfelsed.

Rough QAPF: Plag: 55%, gmass K-spar 15%, Chloritised mafics: 25%, groundmass opaques 5%.

Field Number		Formation:					
PI22 *		Ibáñez Andesitoid (Hornfelsed)					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
274424	4871800		5	5	70	0	80
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
			3	15			
Other components:		Others:	Total:				
Calcite/epidote		2	100				
Final Rockname							
Hornfels (Basaltic andesitic lava.)							

Microscopic textures (PI22):

Altered porphyritic volcanic rock, with remnant euhedral glomeroporphyritic plagioclase phenocrysts in groundmass of pilotaxitic feldspars with oxidised mafics and occasional quartz microphenocrysts. Epidote, calcite, quartz, chlorite occur as alteration, both of phenocrysts and groundmass, and as void filling material. Mafics are either altered to pale chlorite with blue interference color or oxidised to hematite. Secondary hematite is disseminated throughout the rock. Occasional patches of quartz occur in groundmass and as secondary euhedral crystals in cavities/veins with calcite.

Large feldspar phenocrysts are euhedral to subhedral crystals up to 1.5–2mm, partly rounded plagioclase, sometimes glomeroporphyritic, some with sieve textures. Alteration to sericite and both crystalline and fine granular epidote is common, but some crystals still ok. ML gives: 7, 17, 17.5, 9, 5, 14, 19.5, = either albite or calcic oligoclase. RI is difficult to measure, but is below medium for fast' and slow' so probably Albite or Albitised.

Groundmass feldspars show well developed pilotaxitic texture, but are also partly altered/sericitised or clayey. Remnant albite and carlsbad twins are common, and RI is well below medium, so Albite appears most common and some k-spar may occur.

Mafics and Opaques are oxidised to reddish opaque hematite in hand specimen, giving a distinct red tinge to rock and thin section. About 15-20 %, including any original opaques and blocky pseudomorphs of ?clinopyroxene.

Estimated Qap: Phenocryst Plag: 10%. Groundmass Plag: 60%. Quartz microphenocrysts:5% Altered mafics and Opaques: 15%, perhaps 5% interstitial anhedral k-spar but difficult to identify due to alteration. Also secondary chlorite/epidote/calcite voidfilling and alteration 5%.

Field Number		Formation:					
PI18 *		Ibáñez Andesitoid (Hornfelsed)					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
271875	4871800		10	1	60	0	71
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
5			5	5			8
Other components:		Others:	Total:				
Epidote		6	100				
Final Rockname							
Albite-epidote facies hornfels (Olivine Basaltic Lava).							

Microscopic textures (PI18):

Fine grained, porphyritic rock with some remnant phenocrysts of plagioclase, now studded with secondary epidote, lozenge or skeletal olivines now altered to ?hematite/iddingsite, and some remnant pyroxenes. Groundmass is fine grained felsitic/pilotaxitic and partly recrystallised or sericitised plagioclase microphenocrysts, altered mafics and hematite opaque, with common secondary epidote, chlorite and maybe quartz.

Remnant Clinopyroxene, probably augite, occur, up to 0.5mm, 3–5%. Some appear partly recrystallised and overgrown, others are altered to chlorite or uralite. Some fine grained pyroxene occnrs in the groundmass, but is difficult to differentiate from the epidote due to small grainsize.

Large opaques are hematite or iddingsite mix, and from pointed terminations and skeletal shape they may be pseudomorphs of quenched textured olivine phenocrysts, subhedral, np to 1.5mm. No unaltered olivine remains, however.

Large feldspars are plagioclase, some up to 5mm, but only 1–2%. Alteration is patches of calcite and green epidote. Some show sieve textures and rounded subhedral shapes.

Groundmass feldspar laths are sub 1mm, partly recrystallised, sometimes to quartz mosaic patches?, and are in intergranular texture with partly altered pyroxene, oxidised opaques, and secondary epidote and chlorite alteration. Some veins of calcite occur. Becke line test of felspar microphenocrysts difficult, but suggests albite or oligoclase.

Estimated primary composition: Oxidised Olivine: 8%. Clinopyroxene3-5%, opaques 5%, Plagioclase laths in groundmass 60%, up to 10% patchy quartz recrystallisation, maybe trace k-spar as anhedral material in groundmass. Hard to tell due to alteration.

A.2.4 Ibáñez Sediments

Field Nnmber	Formation:					
F24B	Ibáñez Sediment					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
287350	4872720					0
Final Rockname						
Dark blue-grey friable to poorly indurated coarsely laminated to thinly bedded well sorted coarse volcaniclastic sandstone.						

Microscopic textures (F24B):

Detrital rock of feldspathic igneous rock fragments and some quartz. Weak bedding parallel development SPO of chlorite.

Common to pervasive alteration of feldspars in rock fragments to isotropic and low RI zeolite, probably analcime, which also occurs as vein fillings.

Minor dissolution seams occur.

Chlorite is common as vein filling, void fill,and alteration product on rims of crystal fragments.

Calcite occurs as vein filling and alteration product.

Most rock fragments appear to be andesitoids, trachytic or pilotaxitic in texture, with much opaque iron oxide alteration product.

Field Number	Formation:					
F2B	Ibáñez Sediment					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
288123	4865027					0
Final Rockname						
Light blue, indurated, moderately sorted, normal and reverse graded tuffaceous fine siltstone to medium sandstone.						

Microscopic textures (F2B):

Weak grading of fragments, and secondary micas in matrix have bedding parallel orientation. Finely laminated on 1–2mm bedding planes, but not obvious in thin section.

Quartz: Fine silt to medium sand sized angular, fractured crystals.

Feldspars: Detrital Plagioclase and K-spar. Sericitised and replaced by calcite in the sandier laminations. Probably sodic or albitised plag. Muscovite common as small, murky patches and plates in the matrix. Has weak bedding parallel SPO. Also present as sericitisation of feldspar clasts.

Other minerals: Leucoxene as opaque, and some red hematite staining and patches among coarser grainsizes. Calcite present as void filling and alteration of feldspars.

Groundmass: Matrix of fine silty material with ghost shard textures in some places, now mostly felsitic texture with small plates of muscovite and patches of ?Zeolite alteration. Some fine silt sized quartz and feldspar fragments.

Field Number F4	Formation: Ibáñez Sediment					
Utm East 288817	Utm North 4866879	CF:	RF:	V:		Subtotal: 0
Final Rockname Moderately sorted angular to subangular medium to coarse sandy tuffaceous feldsarenite.						

Microscopic textures (F4):

Moderately sorted angular to subangular medium to coarse sandstone, composed of feldspar, rock fragments and quartz, 40–50% feldspars, 30% rock fragments, 10% quartz, along with minor proportions of silicic cherty cement, calcite, clay, chlorite also present as void filling and cement.

Rock fragments are pilotaxitic andesitoids, also devitrified tuffs and rhyolitoid fragments, max size coarse sand or very small granules. Some felsitic deformed fragments may be devitrified and recrystallised detrital pumice and glass shards.

Trace minerals include biotite, magnetite, hematite, clays, leucoxene, sericite.

Field Number CP82B	Formation: Ibáñez sediment (Hornfelsed)					
Utm East 278803	Utm North 4869300	CF:	RF:	V:		Subtotal: 0
Final Rockname Albite-Epidote facies hornfels (tuffaceous fine sandstone.)						

Microscopic textures (CP82B):

Fine grained rock, with groundmass of equigranular fine granoblastic quartz/feldspar, recrystallised from tuffaceous or tuff precursor?

Occasional remnant broken detrital bipyramidal volcanic quartz and feldspar clasts, sometimes overgrown with new material from recrystallising groundmass. Sericite present as feldspar alteration, sometimes recrystallised into small plates of muscovite. Low birefringence, low RI uniaxial negative grains may be cristobalite, while low RI biaxial high 2v grains look to be Low Albite.

Subhedral/euhedral randomly orientated or decussate biotite occurs, commonly chloritised. Concentrated along vein areas or coarser grained patches reflecting original grainsize changes.

Trace muscovite, epidote, magnetite as opaque, oxidised to hematite and occasionally occurring with leucoxene.

Field Number CF19	Formation: Ibáñez Sediment (Hornfelsed)					
Utm East 271642	Utm North 4878393	CF:	RF:	V:		Subtotal: 0
Final Rockname Albite-Epidote facies hornfels (after tuffaceous sediment).						

Microscopic textures (CF19):

Hornfelsed Ibáñez tuff with faint fiamme texture and occasional altered feldspar and quartz crystal fragments, in fine grained felsitic matrix, recrystallised in places to coarse mosaic quartz with decussate textured porphyroblasts of muscovite and biotite mica and chlorite. Possibly also some andalusite, but very small and difficult to identify.

Field Number CP79A	Formation: Ibáñez Sediment (Hornfelsed)					
Utm East 279295	Utm North 4869470	CF:	RF:	V:		Subtotal: 0
Final Rockname Hornblende Hornfels (tuffaceous fine sandstone)						

Microscopic textures (CP79A):

Very fine grained rock with faint subhorizontal compositional banding reflecting original sedimentary structure.

Matrix is fine grained granoblastic mosaic of quartz and feldspar, often with small subhedral grains of biotite and sericitic muscovite in decussate texture. Feldspar 2v high where measureable, with Rl well below quartz, fast well below epoxy, slow moderatly below so probably Low albite.

Clots or poikiloblastic patches of high Rl colourless andalusite and altered sericitised ?cordierite occur, iu bands parallel to original bedding. Biotite grains often occur in patchy rim around these altered cordierites or andalusite porphyroblasts.

Trace authigenic euhedral uniaxial negative brown tourmaline.

Opaques are small, blocky, probably magnetite, but also much yellow iron staining and patches of semi-opaque reddish hemitite.

Field Number	Formation:					
PI43α	Ibáñez sediment.					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
271625	4871575					0
Final Rockname						
Reworked crystal tuff/ well sorted, thickly bedded to laminated and graded crystal rich, clast supported tuffaceous coarse to medium sandstones.						

Microscopic textures (PI43α):

Quartz: Size ranges sub 0.125mm through to 2mm. 10% in sandy material, 1–5% in pumices. Commou, as angular fractured crystals in sandy and silty material, and as phenocrysts in pumice clasts.

Feldspars: Detrital in sandy material, plagioclase mostly Albite or albitised, maybe some oligoclase, and Kspar present, altered, subhedral and fractured. Sizes range sub.125 to 3mm. About 10–15%.

Biotite: Altered, trace, in pumice clasts, altered to mafics and chlorite, surrounded by chlorite halo.

Muscovite: Trace as sericite, and occasional crystal, presumably of xenolithic origin.

Other minerals: Trace calcite, trace epidote. Chlorite, Dark green pleochroic. Common in Groundmass and as alteration product. Maybe some serpentine as well.

Groundmass: Fine, silt-sized quartz/felspar/opaques, occasional ?mica. Common chlorite patches and alteration, recrystallised/felsitic material, probalby devitrified glass, murky brown streaks in fine sandy layers at base of coarse pumice horizon possibly carbonaceous material or ?stylolitic veins, or clay streaks.

Pumices are Large, 5–15mm devitrified pumice fragments, with quartz/Sodic plag/trace Sanidine/biotite mineralogy. Also sub-rounded porphyritic felsitic rhyolite lithics, with trace pyroxene. (large material is clast supported.)

A.3 Coyhaique Group

A.3.1 Katterfeld Formation

Field Number	Formation:					
GA13	Coyhaique Group (Katterfeld)					
Utm East	Utm North	QF:	RF:	FF:		Subtotal:
278000	4876940					0
Final Rockname						
Recrystallised limestone hardground/concretion in Katterfeld shales.						

Microscopic textures (GA13): Small fragment of septarian calcite concretion layer in muddy shales, draped with fine silty shale layers with some quartz draped over finely granular sparry calcite clast or concretion which shows faint internal bedding, occasional quartz clasts and secondary euhedral 0.2mm pyrite, and wedge shaped internal fractures filled with coarse grained sparry calcite. Higher relief wedge or hexagonal patches in calcite may be dolomite.

Possibly small limestone hardground from blackshales, partly recrystallised into concretions/nodules.

Field Number	Formation:					
F43	Coyhaique Group (Katterfeld)					
Utm East	Utm North	QF:	RF:	FF:		Subtotal:
283314	4868800					0
Final Rockname						
Katterfeld Blackshale.						

Microscopic textures (F43): Finely laminated shale or siltstone, with normally graded laminations of fine grained semi opaque carbonaceous organic material and minor quartz-feldspar silt component, and one ?andesitoid Rock fragment. (Note, hand specimen has sulphurous smell when cut or broken.)

Calcite veining has invaded and contorted some laminations while sediment was still unconsolidated, giving rise to some "micro-diapiric" structures. These calcite veins themselves are contorted, with the thickest veins parallel to laminations. There is some dissolution and pressure solution seaming evident, especially at veins.

Field Number	Formation:					
CF22	Coyhaique Group (Katterfeld) (Altered)					
Utm East	Utm North	QF:	RF:	FF:		Subtotal:
272832	4878335					0
Final Rockname						
Hornblende hornfels (Katterfeld Formation).						

Microscopic textures (CF22): Strongly silicified and partially hornfelsed laminated muds and very fine silts. Laminations are from 0.5–3mm, with finer laminations partially recrystallised to fine grained sericitic mica with strong lamination parallel LPO, and coarser layers partly mosaic recrystallised quartz/feldspar grains and cherty rock fragments in a silty matrix. Some areas have incipient "spotty" porphyroblast growth, but metamorphic mineral difficult to identify. Quartz veins with muscovite grains along vein margins occur.

Silty layers are composed of cherty rock fragments with about 20–30% quartz and sodic plagioclase fragments, up to 0.3mm, and have matrix of cherty and micaceous material. Coarser grained (.3–0.4mm) thick silty layers with ripple shapes also have porphryoblasts of granular or radial clusters of blue-green or brown-blue pleochroic amphibole, probably metamorphic hornblende. Opaque euhedral pyrite porphryoblasts occur disseminated throughout, in both silty and muddy layers.

A.3.2 Apeleg Formation

Field Number		Formation:				
F41		Coyhaique Group (Apeleg)				
Utm East	Utm North	QF:	RF:	FF:		Subtotal:
283750	4869190	30	30	25		85
Other components:	Others:	Total:				
Calcite voidfill	15	100				
Final Rockname						
White to grey well sorted thickly bedded normal and reversely graded medium and coarse sandy volcaniclastic 'feldspathic litharenite'. Clast supported, matrix poor.						

Microscopic textures (F41): White to grey well sorted thickly bedded normal aud reversely graded medium and coarse quartzofeldspathic sandstone. Clast supported, matrix poor.

Dominated by quartz and rock fragments, with slightly less feldspar.

About 30% Angular volcanic quartz fragments, originally subrounded but now overgrown with secondary authigenic quartz to angular shapes.

Rock fragments also about 30%, felsitic and cherty mosaic quartz/feldspar recrystallised silicic volcanics, with minor well rounded andesitoid or trachytoid fragments. Devitrification and recrystallisation to mosaic material has contributed significantly to cementing the sandstone. This may be thermally enhanced by F40 intrusive.

Feldspar is murky, clayey sodic plagioclase, mostly oligoclase or albite, with murky altered subhedral subangular to subrounded crystal fragments, often sericitised. About 25%

Minor minerals are some secondary authigenic or low grade met muscovite, also calcite as void filling, and common quartz overgrowths on quartz grains, visible due to dust on original grain margins.

RF:30, Q:30 Feldspar:25, secondary quartz overgrowths, calcite voidfilling, etc 15%, plots as a feldspathic litharenite by Folk et al. (1970) classification.

Field Number	Formation:					
CF17	Coyhaique Group (Apeleg) (Altered)					
Utm East	Utm North	QF:	RF:	FF:		Subtotal:
272832	4879701					0
Final Rockname						
Horblende hornfels (Apeleg Formation).						

Microscopic textures (CF17): Well recrystallised sandstone, probably once a tuffaceous sandstone, but now most clasts and matrix are cherty mosaic quartz and feldspar with fine granular decussate biotite and pyrite. Section cut a bit thick, some quartz is showing yellow and red interference colours.

Relict sand grain textures are present, with most grains now cherty mosaic quartz feldspar, and with rims of granular altered mafic minerals or decussate biotite. Quartz has also occurred as large grains as void filling, together with amphibole and opaques. Original sodic plagioclase grains are still present, but appear murky and albitised. Granular green subhedral to amorphous material in matrix and rimming clasts is possibly uralitic amphibole, while blue-green and brown-green hornblende also occur. Minor amounts of muscovite occur, also in decussate texture in matrix. Remnant grains of K-spar occur also.

Veins have chlorite along rims and scapolite (straight extinction, fast along cleavage, uniaxial negative) as vein filling. Possibly retrograde? Hornblende hornfelse facies Apeleg Sandstone.

Field Number		Formation:					
CF21		Coyhaique Group (Apeleg) (Altered)					
Utm East	Utm North		QF:	RF:	FF:		Subtotal:
272995	4878050		15	65	10		90
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
			3				
Other components:		Others:	Total:				
Mud/silt matrix		7	100				
Final Rockname							
Apeleg Formation moderately well sorted medium to coarse sandy, thickly bedded and foreset crossbedded, volcaniclastic litharenite.							

Microscopic textures (CF21): Moderately sorted to well sorted medium to coarse sandstone with ripup clasts of fine siltstones and mudstones. Sand grains are quartz/rockfragments/feldspar, clast supported, sorted and normally graded, with 5–50mm ripup clasts of semi consolidated mudstone/siltstone, with some ripple/scour structures within the ripup clasts.

Quartz grains make up about 15% of the rock, ranging from broken and embayed rounded volcanic quartz grains, to occasional rounded grains of polycrystalline metamorphic quartz with some mica plates. Volcanic quartz fragments dominate, generally 1–1.5mm, but up to 4mm.

Feldspar grains are about 10%, murky altered fractured or subrounded grains with incipient seritific alteration. Some are sieve textured sodic or albitised volcanic plagioclase, and some untwinned or carslbad only twinned grains with RI well below epoxy may be K-spar.

Rock fragments make up about 65% of rock, and are from medium sand sizes up to 30–50mm ripup clasts. Sand grains are well sorted, subrounded to rounded, while ripup clasts are angular and sometimes deformed. Most RF are either cherty or felsitic textured silicic tuffaceous sediment or silicic volcanic rock fragments, or pilotaxitic porphyritic andesitic rock fragments. Large ripup clasts are of silty mudstone with ripple structres and some deformation, indicating they were not lithified. Occasional polycrystalline metamorphic quartz grains occur.

Rock is clast supported, with minor muddy or silty matrix (7%) and some chlorite occuring as void filling (3%).

Field Number		Formation:				
CF17D		Coyhaique Group (Apeleg) (Altered)				
Utm East	Utm North	QF:	RF:	FF:		Subtotal:
272832	4879701	15	75	5		95
Other components:	Others:	Total:				
Cement and void fill	5	100				
Final Rockname						
Albite-epidote facies hornfels: Apeleg Formation very coarse sandstone to granule/pebble conglomerate. (Litharenite by Folk/Andrews/Lewis(1970))						

Microscopic textures (CF17D): Crossbedded graded rock, from fine pebble/granule conglomerate to very coarse sandstone in hand specimen. Thin section is cut at base of crossbedding, showing granules of quartz and rock fragments above very fine sandstone to silt, with slight founder structures. Then laminations of moderately sorted, clast supported small granules and very coarse sands, both normally and reverse graded, with some fine sand interstitial to larger clasts. Rock is partially recrystallised with cherty or felsitic and quartz mosaic recrystallisation of silicic rock fragments and mosaic silica cementation. Quartz fragments have overgrowths visible through dust rims. Mosaic quartz occurs as void filling, and as cement, along with epidote/chlorite/ clusters as void filling and alteration/metamorphism. About 15% Quartz, 5% feldspar, 75% rock fragments, 5% chlorite/epidote/cherty quartz as cement and void infilling.

Quartz occurs mostly as angular to sub angular and rounded volcanic quartz fragments, often with secondary rims/overgrowths, but also as sand grains and granules with granoblastic mosaic metamorphic grains, some with very fine grainsizes reminiscent of cataclastic quartz textures.

Some volcanic grains have recrystallised into two or more subgrains, perhaps indicating slight strain effects associated with the Cerro Farellón intrusions.

Rock fragments are felsitic, cherty or mosaic recrystallised grains and granules of mainly silicic volcanic or volcaniclastic material, rounded to subrounded and sub angular. There are lesser proportions of pilotaxitic andesitic fragments, and the granoblastic quartzite fragments mentioned above. Finer grainsizes of cherty or felsitic textured clasts were probably fine ashy or silty volcaniclastic sediments, while the coarser grained felsitic to mosaic recrystallised clasts may have been rhyolitic clasts or ignimbritic clasts. Little internal texture survives in most rock fragments except the pilotaxitic, porphyritic andesitic clasts and the granoblastic or cataclastic quartzite fragments. Some rock fragments are replaced or altered by mosaic quartz/feldspar, others spotted with epidote and chlorite porphyroblasts.

Feldspars mainly occur within volcanic rock fragments, although individual subrounded to angular coarse sand size grains occur, mainly of altered, sericitised sodic plagioclase.

Field Number		Formation:				
CF17C		Coyhaique Group (Apeleg) (Altered)				
Utm East	Utm North	QF:	RF:	FF:		Subtotal:
272832	4879701	25	45	20		90
Other components:	Others:	Total:				
Matrix	10	100				
Final Rockname						
Albite-Epidote Facies Hornfels (Apeleg Fm.)						

Microscopic textures (CF17C): Partially recrystallised coarse sandstone, with moderately sorted, clast supported subangular to angular grains of quartz, cherty altered rock fragments and altered or sericitic feldspar, partially recrystallised and silicified.

Quartz grains are about 25%, mainly angular fractured volcanic quartz, although some mosaic grains of metamorphic quartz are present. Some grains are partially overgrown with mosaic quartz grains from nearby altered rock fragments and from interstitial silicification.

Rock fragments are about 45%, angular to sub rounded cherty or mosaic quartz feldspar patches, possibly recrystallised from fragments of silicic tuff or rhyolites. Some fragments contain remnant pilotaxitic texture. Differing clasts can be determined from brown staining in ppl or changes in recrystallisation textures.

Feldspars are mainly murky altered grains of sodic plagioclase, often sericitised, albitised. About 20%, but difficult to identify grains.

Rock is clast supported, but pore spaces are filled by cherty mosaic quartz and quartz/feldspar cement/recrystallisation material, together with occasional spots or patches of radial chlorite/epidote and granular subhedral blocky pyrite. Some pyrite/chlorite/epidote veins also occur, parallel to bedding. Matrix cherty cement and chlorite/epidote/pyrite make up remaining 10% of rock.

Field Number		Formation:				
CF17B		Coyhaique Group (Apeleg) (Altered)				
Utm East	Utm North	QF:	RF:	FF:		Subtotal:
272832	4879701	5	75	10		90
Other components:	Others:	Total:				
Matrix	10	100				
Final Rockname						
Hornblende Hornfels (Apeleg Fm.)						

Microscopic textures (CF17B): Poorly sorted small pebble to gravel conglomerate, roughly trough crossbedded in the field, spotty with black, purple and green clasts, secondary epidote and magnetite.

Pebbles are clast supported, rounded to subrounded granules to gravel sizes, either cherty or felsitic textured altered rhyolitic tuff and rhyolite fragments or altered and sericitised porphyritic or pilotaxitic andesitic to dacitic volcanic fragments, with an interstitial matrix of coarse sand sized rock and crystal fragments, of rhyolitic and andesitic debris, sodic plagioclase and volcanic quartz. Feldspars are altered and sericitised, as are andesitoid/dacitoid clasts. Cherty mosaic recrystallisation of felsic clasts is common.

Secondary minerals are green length slow fibrous chlorite as void filling and alteration mafic minerals, and clusters of granular epidote and magnetite around clastic grains. Some grain rims have nucleated acicular colourless tremolitic amphibole.

About 75% rock fragments, 10% feldspar fragments, 5% quartz frags and 10% matrix and secondary metamorphic minerals.

A.4 Divisadero Formation

A.4.1 Tuffs and Ignimbrites

Field Number	Formation:					
GA14C	Divisadero Tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
278990	4877460	1	0	99		100
Final Rockname						
Accretionary lapilli Tuff.						

Microscopic textures (GA14C): Fine grained tuff with partially flattened ovoid accretionary lapillifrom 2–10mm, composed of successive layers of fine devitrified chertyash with occasional very small quartz fragments, with interstitialmatrix of devitrified ash with fine cherty texture and remnantvitroclastic shard textures, sometimes pseudomorphed by calcite. Fine disseminated pale green chlorite common.

Field Number	Formation:					
LF5T *	Divisadero Tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
272748	4938582	1	2	97		100
Final Rockname						
Partially welded or sintered and subsequently devitrified upper part of rhyodacitic-rhyolitic vitric tuff/ignimbrite.						

Microscopic textures (LF5T): Again, very similar to the two previous samples, a devitrified vitroclastic rock, crystal poor, with varying degrees of recrystallisation.

This rock is dominated by devitrified ash, and has less pumice than thepreceding two samples. Vitroclastic shard textures, slightly flattened,are visible in both cpl and ppl, but less so in the former because of amix of felsitic and spherulitic or mosaic quartz/feldspar replacement ofthe shards. Common finegrained microlites occur in shardmaterial. Unlike the former two samples, secondary quartz is notconfined to fiamme but occurs disseminated through both ash matrix andfiamme. Otherwise, shards are replaced by irregular spherulitic radialtextures rather than felsitic textures.

Sparse crystal fragments include a trace of green-brown biotite, altered in places to opaque brown iron oxides, and about 1% Sodic plagioclase feldspar, with patchy alteration to K-spar along fractures and cleavage,more altered than the middle sample, but less so than the base. Also trace amounts of blocky magnetite crystals and maybe altered biotite.

Alteration includes patchy sericite and clots of reddish-opaquehematite, perhaps after biotite from shapes. and fractures.

Lithic fragments, 2%., occur as 1–3mm oxidised intermediate volcanicand volcaniclastic rock fragments. Some have served as nuclei forquartz/feldspar mosaic recrystallisation.

Field Number	Formation:					
F27A *	Divisadero Tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
287660	4873900	37	1	62		100
Final Rockname						
Welded and devitrified rhyolitic ignimbrite						

Microscopic textures (F27A): Quartz-Feldspar fragment rich ignimbrite, with about 15% quartz and 15–20% feldspar and occasional biotite in a devitrified brown ashymatrix. Secondary calcite and iron oxide staining occur as alteration.

Quartz is about 10–15%, broken subhedral bipyramids, rounded aud embayed, up to 2mm, often fractured or broken.

Feldspars are altered, subhedral and broken, about 20%, up to 2mm. Calcite and cherty-textured sericitic material are common alteration/replacement, but most crystals have remnant unaltered or partially altered feldspar,both sodic plagioclase and occasional k-spar.

Biotite is cleavage fragments or subhedral booklets, unaltered, greenbrown pleochroic, about 1% to trace, up to 0.5mm.

Opaques are oxidised to hematite/goethite, reddish in reflected light,up to 1mm.

Lithic fragments are sparse, occasional 0.5–1mm angular fragments of immature volcaniclastic sandstones/siltstones.

Matrix is about 60–65%, brown devitrified ashy material with incipieut felsitic recrystallisation texture in cpl, but with shard textures andflattened pumice fiamme, up to 5–6mm, visible in ppl. Common secondary hematite staining and some fiamme seem replaced by opaque hematite. Voidspace filled with calcite or cherty sericitic material, some times with opaque hematite.

Field Number	Formation:					
CD7T *	Divisadero Tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
267771	4946000	17	1	82		100
Final Rockname						
Moderately welded but strougly devitrified, recrystallised and maybe vapour phase altered upper part of thick vitric tuff.						

Microscopic textures (CD7T): Section is cut a little thick (Yellow Quartz.)

Still fairly uniform fine grained vitric tuff, with the same proportion of crystal and lithic fragments as the middle sample, about 20%,remaining 80% devitrified glassy ash and pumice. Crystals are about 15%, lithics 3–5%, size ranges about 0.4mm to 4mm, avg sub 1mm. Quartz and sodic plagioclase still most common, perhaps some k-spar.

Quartz is rounded, embayed and often fragmeutal bipyramids, up to 3mm. About 7%. Some embayments and voids coutain devitrified glassy material.

Feldspar is about 10%, subhedral and euhedral crystals, often fractured, someglomeroporphyritic, up to 2mm. Alteration is common, usually slight murkiness of crystals, but seems more advanced than both the basal and middle sample. Sodic plag, albite, seems to dominate, same as basal sample.

Other crystal frags present: Trace magnetite, often with hematite alteration.

Lithics are the same as the middle sample, about 1%, up to 1mm and are still slightly oxidised and devitrified angular fragments of tuff and ignimbrite.

Matrix is devitrifed ash shards, but vitroclastic texture is very faint,only just visible in ppl, otherwise matrix is grainy brown featureless material like the middle sample. However, in cpl the matrix is both devitrified and recrystallised to a very coarse felsitic texture and also very much to a finely granular quartz/feldspar mosaic texture. This may be an effect of vapour phase alteration on the upper parts of the tuff. No evidence of fumarole action was seen in the field, however.

Field Number	Formation:					
F48 *	Divisadero Tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
281710	4868830	27	1	72		100
Final Rockname						
Welded and Devitrified Rhyolitic Ignimbrite.						

Microscopic textures (F48): Ignimbritic rock with fragmental quartz aud altered feldspars, in poorly welded glass shard and pumice fiamme matrix. Shard textures visible, deformed, mostly devitrified to felsitic texture iu cpl.

Crystal fragments are about 27%. Quartz is fragmental and embayed bipyramids, up to 3mm. About 3%. Plagioclase feldspar is about 15–20%, fractured euhedral and subhedral crystals, altered to sericite, calcite and clays, but ML on remnants indicates Oligoclase, about An28%, from 21 degree reading. Sparse small, biotite, brown pleochroic cleavage fragments, sometimes murky with iron oxides or replaced with hematite, about 1%. Also trace to 1% blocky opaque magnetite, also altered to iron oxides, and with associated apatite. Opaques (1%) are often square or blocky, up to 1mm, probably magnetite, but now replaced by leucoxene or murky hematite. Biotite may also occur as secondary vapour phase mineral in voids.

Groundmass is devitrified glass shards and flattened pumice fiamme. Shards are clearly visible in ppl, flattened and deformed, and devitrified to quartz/k-spar felsitic texture in cpl, while pumice fiamme are flattened and spherulitic in radial or concentric bands. Groundmass is faintly stained red or orange by hematite staining. Lithic fragments sparse and small, usually 1mm or less, felsitic textured intermediate to silicic volcanic fragments. 1% or less.

Field Number	Formation:					
F47B	Divisadero Tuff/Ig					
Utm East	Utm North	QF:	RF:	FF:		Subtotal:
281980	4868360					0
Final Rockname						
Light blue well sorted fine sandy to silty partially devitrified ashy tuffaceous fine sandstone.						

Microscopic textures (F47B): Fine grained tuff or tuffaceous rock with trace glass shard remnants, but dominated by fine grained isotropic and patchy felsitic groundmass,with small broken crystal fragments of quartz, feldspar and occasional pyroxene, matrix supported in partially devitrified felsitic and altered ashy groundmass. Some secondary chlorite, and patches of dark brown,almost opaque iron oxides. About 15–20% crystal fragments, the remaining 75–80% devitrifying ashy matrix material. Very few rock fragments at all.

Field Number	Formation:					
LF5M *	Divisadero Tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
272748	4938582	0.5	5	94.5		100
Final Rockname						
Welded and devitrified crystal poor vitric rhyodacitic or rhyolitic tuff/ignimbrite.						

Microscopic textures (LF5M): Middle sample is also crystal poor, with less than 1% crystals orcrystal fragments, and is likewise dominated by a well preserved,eutaxitic pumice fiamme texture in a matrix of devitrified vitroclasticm ash. Welding is well developed, with both pumices and shards flattened and attenuated. Vitroclastic textures stand out well in ppl and cpl, and unlike the basal sample, where matrix ash has devitrified to felsitic texture in cpl, whereas here the vitroclastic shard texture is still visible in cpl, possibly due to lesser welding effect and less advanced devitrification. Some shards display internal devitrification/rexlln to felsitic or semi-spherulitic texture, but this recrystallisation does not cross shard boundaries, suggesting a lesser welding effect.

Pumice fiamme are up to 10mm, lensoidal and flattened. Recrystallisation varies, with some a mass of small spherulites and others a mix of large diffuse spherulites and irregular quartz/feldspar mosaic recrystallisation. Crystals within some pumices have "tails" of quartz/feldspar mosaic material reminiscent of pressure shadows, and voids have mosaic material as well.

One or two primary quartz crystal fragments occur as small fractured crystals. Otherwise, quartz is a secondary recrystallisation mineral.

Sodic plagioclase occurs, less than 1% of the rock, subhedral-euhedralfragmental crystals. Sodic plagioclase is fresh or markedly less altered than that in the basal sample, and is also less internally fractured. Some crystals are zoned and glomeroporphyritic.

Opaques are oxidised to hematite/goethite. Biotite is trace only, lessthan in the basal sample, and is still green-brown cleavage fragments.

Lithic fragments are sparse between 3–5%, and are mostly fragments of other vitroclastic tuffs and ignimbrites, although some are oxidised intermediate to felsic volcanics.

Field Number	Formation:					
LC2 *	Divisadero Tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
286560	4947721	4	3	93		100
Final Rockname						
Crystal poor, welded core of LC rhyodacitic-rhyolitic ignimbrite.						

Microscopic textures (LC2): Devitrified crystal poorignimbrite. Well developed pumice lenses in eutaxitic texture, but devitrification of groundmass ash has partly obscured shard outlines. Pumices are replaced with sericitic materialand felsitic or mosaic quartz/feldspar, very fine grained. Groundmass ash shards are visible in ppl, but under cpl most have recrystallised into fine grained felsitic material, although some shards show semi-spherulitic textures.

Lithic fragments are sparse, 1–3%, angular, up to 5mm, 10 in handspec, and are either fragments of tuffaceous sediments, rhyoitoid tuff,ignimbrite or intermediate volcanic rocks.

Crystals are rare, most are fragmental sodic plagioclase, but some muscovite cleavage sections are present, including iron oxides along cleavage planes. These may be altered biotite, 1%. Feldspars are less than 3%, sericitised, small crystals. No primary quartz.

Some chlorite occurs as alteration associated with cavities and mafic volcanic lithics/xenocrysts, as does goethite/hematite staining.

Secondary quartz fills some fine vertical fractures, similar to LC1 sample.

Field Number	Formation:					
GA1 *	Divisadero Tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
286670	4871970	27	0	73		100
Final Rockname						
Lithic poor sintered rhyolitic ignimbrite.						

Microscopic textures (GA1): Rock is pyroclastic, with colourless broken quartz phenocrysts and murky, euhedral or fractured altered feldspars in light brown matrix with faintly visible shard texture, and traces of biotite, occasional oxide patches. CPL exposes many more shards in groundmass, showing some flattening, widespread devitrification and quartz mosaic rexlln, finegrained though. Some wrap-around structures on phenocrysts.

Quartz is 8–10%, up to 5mm, rounded, fractured and embayed bipyramids. Groundmass contains much mosaic quartz, mostly fine grained from recrystallised glassy material, but larger crystals have grown around some altered feldspars.

Feldspars are entirely altered, but are about 15 %, up to 4mm,subhedral and euhedral, some fractured, all now psedomorphed by colourless cherty textured sericite, but also some invasive quartzmosaic occurs along grain boundaries. Under reflected light the crystals are partly altered to white clay.

Biotite,2 %, less than 0.5mm, green to brown pleochroic, usuallyeuhedral booklets or fragments.

Essentially no lithic fragments.

Groundmass is felsitic or mosaic recrystallised ash to quartz, etc, and under cpl partly flattened shards show as anisotropic partly devitrified glass or as cherty felsitic material, sometimes coarsened to quartz mosaic. Opaques are probably hematite, after magnetite/ilmenite, and are surrounded by reddish haloes of goethite staining.

Field Number	Formation:					
LF5B *	Divisadero Tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
272748	4938582	1	5	94		100
Final Rockuame						
Rhyolitic to rhyodacitic welded and devitrified crystal poor basal vitrophyre of a vitric tuff/ignimbrite.						

Microscopic textures (LF5B): This rock is quite crystal poor, with less than 1% crystals or crystal fragments, and is dominated by a well preserved eutaxitic pumice fiamme texture in a matrix of devitrified vitroclastic ash. Welding is well developed, with both pumices and shards flattened and attenuated. Vitroclastic textures stand out well in ppl, and pumices are hard to spot, but in cpl the vitroclastic groundmass is uniformly felsitic, and the pumice fiamme are easily discernible as wisp ended lenses or streaks with fine grained quartz/feldspar cherty or mosaic recrystallisation texture.

Green-brown Biotite and sodic plagioclase together are about 1% of the rock, and are subhedral-euhedral fragmental crystals. Sodic plag is quite altered, sericitised or seamed with cracks. One or two quartzcrystal fragments occur. Some biotite occurs inside pumices. Opaques are oxidised to hematite/goethite.

Lithic fragments are sparse between 1–5%, and are mostly fragments of other vitroclastic tuffs and ignimbrites, although some are oxidised intermediate to felsic volcanics. Some of these lithic fragments have also been attenuated and flattened along with the pumices.

Field Number	Formation:					
CF43	Divisadero Tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
273571	4885582	26	1	73		100
Final Rockname						
Partially hornfelsed rhyolitic tuff.						

Microscopic textures (CF43): Partially hornfelsed tuff with secondary epidote and widespread sericitisation of groundmass vitroclastic shard textures.

About 5% fragmented and embayed or rounded bipyramidal quartz, about 0.2–2mm.

Feldspars are mainly subhedral fractured and broken sodic plagioclase, albite by low RI, but also with patchy alteration to K-spar, some primary sanidine crystals present. About 20%, 0.2–4mm crystal fragments.

Biotite — trace to 1%, altered and chloritised green brown biotitecleavage flakes. Groundmass is felsitic textured devitrified ashy material and partially crushed pumice fragments, with vitroclastic textures pseudomorphed by sericitic micas replacing groundmass shards and pumice fragments.

Lithic fragments are rare, 1% or less, fragments of sub-angular tuffand tuffaceous sandstones.

Incipiently metamorphosed with secondary epidote in groundmass, and replacement of shards by sericitic micas, plus also albisation of feldspars.

Field Number	Formation:					
CD12T *	Divisadero Tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
267771	4946000	2	1	97		100
Final Rockname						
Lithic and crystal poor welded and devitrified upper parts of a rhyolitic vitric ignimbrite/tuff.						

Microscopic textures (CD12T): Top sample is more a reddish-brown to brown vitroclastictuff/ignimbrite, still with well developed vitroclastic texture in matrix with flattening and devitrification of shards, crystal poor, but with lithics up to 6mm, pumices up to 2cm. Very similar to the base and middle samples, perhaps with a little more pumice, but also the introduction of more oxidation (red-brown stain, rather than brown) anda little more alteration. Unusual red spherulites occur, up to 3mm or 4mm at their largest, and have remnant vitroclastic texture at centres. Occasional quartz filled fine veins occur, like middle sample.

Crystals are still sparse, about 1–2%, mainly either 0.5–2mm subhedral fractured and maybe zoned sodic plagioclase (section T-a -11, so An% about 3%, Albite) or occasional high sanidine , with trace small cleavage flakes or 'booklets' of pleochroic green-brownbiotite. Biotite is more altered, with some opaques along cleavage, and sometimes altered to green chlorite. Some biotite occurs within the pumices.

Pumice fragments are more common, still wisp-ended lensoidal fragments and partly flattened angular fragments, and as with middle, some appear quite blocky and a little less flattened. Devitrification textures areas with the other samples, with some showing felsitic and incoherent spherulites, some larger pumices with small, well developed spherulites and some with quartz/k-feldspar mosaic textures, and most show two or more of these textures. Spherulitic textures seem a little more common. Some pumices contain sodic plagioclase fragments.

Lithics are rarer than the two lower samples, and consist of small, sub1mm oxidised intermediate volcanics, 1%.

Matrix is red to brown oxide/hematite-stained ash/glass shards in a felsitic brown material (showing remnants of finer shards, and with fine opaque microlites) Flattening of shards and eutaxitic vitroclastic texture is still present, but less compaction has occurred than in lower samples. Wrap-around textures are faint, not well developed. Individual shards have either felsitic or partial spherulitic devitrification and recrystallisation textures, and show up in both ppl aud cpl. Some also show fine, cherty quartz mosaic textures. Unlike both lower samples,occasional large spherulites have nucleated in the welded vitroclastic matrix, and are up to 2–3mm, simple radial or partly irregular red stained spherulites.

Field Number	Formation:					
CD12B *	Divisadero Tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
267771	4946000	1	3	96		100
Final Rockname						
Devitrified welded basal ignimbrite.						

Microscopic textures (CD12B): Brown vitroclastic tuff/ignimbrite, well developed vitroclastic texture in matrix with flattening and devitrification of shards, crystal poor,but with lithics up to 6mm, pumices up to 2cm.

Crystals are sparse, less than 1%, and are either 0.5–2mm subhedral fractured sodic plagioclase or occasional cleavage flakes of pleochroicgreen-brown biotite.

Pumice fragments are wisp-ended lensoidal fragments, or partly flattened angular fragments with stretched-vesicle textures still visible. All are partly or completely devitrified, with varying degrees, with some showing felsitic and incoherent spherulites, some larger pumices with small, well developed spherulites and some with quartz/feldspar mosaic textures, and most show two or more of these textures.

Lithics are angular or sub angular to rounded oxidised fragments of intermediate volcanic rocks or siliciclastic volcaniclastic sediments. Up to 5mm, but most sub 1mm. 3%

Matrix is brown-stained ash/glass shards in a felsitic brown material (showing remnants of finer shards.) Somewhat flattened and eutaxitic vitroclastic texture is well developed. Wrap-around textures are present around lithics and crystal fragments. Individual shards have either felsitic or partial spherulitic devitrification and recrystallisation textures, and show up in both ppl and cpl. Some also show fine, cherty quartz mosaic textures.

Field Number	Formation:					
CF39 *	Divisadero Tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
279587	4879590	21	3	76		100
Final Rockname						
Welded and devitrified Rhyolitic Ignimbrite.						

Microscopic textures (CF39): Partly devitrified welded ignimbrite. Colourless or brownish devitrified and eutaxitic ash matrix bears large skeletal crystals of quartz, euhedral feldspars, as well as lithics of rhyolite, flattened and devitrified pumices, etc.

Quartz Crystals 8-10%, Gmass, 30-40% , is present as fragmentalcrystals, up to 4mm, 8mm in some pumices, and is both euhedral beta quartz and/or rounded, embayed and sometimes skeletal and fragmental crystals. Also widespread in groundmass and pumices as quartz mosaic recrystallisation of vitric material, and as vein filling.

Feldspars are about 10%, euhedral 0.3–4mm, sometimes fractured, sometimes glomeroporphyritic. RI indicates Albite, and some crystals with no albite twinning and strong becke line may be K-spar, perhaps sanidine, probably most as groundmass felsitic material.

Trace to 1% green-brown biotite occurs, however it is unusually altered with the plates levered apart along cleavage planes by fine mosaic quartz.

Bright green pleochroic mineral occurs, in amorphous masses within fiamme or cavities, or as replacement of mafics. Probably chlorite, maybe amphibole after pyroxene in some of the replaced crystals.

Rock fragments are sparse, angular, felsitic textured devitrified tuff and tuffaceous sediment, 1–3%.

Groundmass ash and glass fragments are strongly eutaxitic, with good flattening and wrap-around textures. Colourless or brown in ppl,Felsitic in CPL, with different grain sizes and recrystallisation levelsto mosaic quartz/feldspar defining shard pseudomorphs, etc. Some larger pumice fragments have developed coarse mosaic textures and some spherulitic textures.

Field Number	Formation:					
LC4 *	Divisadero Tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
286560	4947721	1	1	98		100
Final Rockname						
Welded and devitrified crystal poor/depletedIgnimbrite, perhaps co-ignimbrite ashfall tuff.						

Microscopic textures (LC4): Red and brown stained fine grained ashy tuff/ignimbrite. Finer than the three lower samples, with almost no pumice fiamme, and also quite crystal and lithic poor.

Crystals present are mostly fragmentary sodic plagioclase, up to 0.8mm, fractured, but otherwise little alteration. Also occasional altered biotite, altered to chlorite or opaques/muscovite mix. 1%

Matrix is flattened and devitrified shards in finer devitrifed brown material, with some wrap-around textures near crystals, and occasional fiamme. Devitrification textures include partial spherulites, especially in fiamme, and felsitic textures. Occasional patch of mosaic quartz/feldspar. Trace calcite as patches and vein fillings near altered fiamme.

Lithic fragments are rare, less than 1mm, usually oxidised fragments of intermediate volcanics or fragments of other ignimbrites. 1%.

Field Number	Formation:					
LF4B *	Divisadero Tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
272635	4938732	26	0	74		100
Final Rockname						
Mauve to brown lithic poor welded basal layers of crystal rich rhyolitic tuff/ignimbrite.						

Microscopic textures (LF4B): Tuff or ignimbrite with embayed and skeletal quartz, altered feldsparand occasional lithic fragment in fine grained, felsitic devitrified brown matrix. Occasional pumice fiamme are difficult to tell apart from the matrix, although some have irregular spherulitic texture.

Quartz is common, 15 %, embayed, fractured and sometimes strongly skeletal bipyramids. Up to 2mm. Some crystals within pumices have nucleated spherulites during devitrification/cooling. Some quartz also as part of recrystallisation of groundmass, lithics and pumices, mostly as small patches of mosaic material. Feldspars are about 10% altered fractured subhedral rounded or euhedral crystals, sometimes slightly zoned partly sericitised large 2v(60) sodic plag, probably Albite. with some epidote alteration also, and some k-spar and calcite replacement in with the sericite. Some crystals have low 2v possibly indicating primary Sanidine as well. Some feldspar crystals have partially overgrown biotite adhering to their rims.

Altered mafic occurs, replaced by calcite, amorphous brown mineral,opaques including leucoxene, and muscovite. May have been about 1–2% biotite. Also some trace blocky magnetite crystals.

Matrix is brown felsitic textured devitrified ash with faint remnant shard texture and occasional devitrified, spherulitic pumice fiamme.

Field Number	Formation:					
LF4T *	Divisadero Tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
272657	4938702	14	1	85		100
Final Rockname						
Dark brick red lithic poor well sintered/welded crystal and pumice poor upper part of rhyolitic tuff/ignimbrite.						

Microscopic textures (LF4T): Very similar to LF 4 B and M, but this upper Tuff or ignimbrite hasless crystal component, a darker colour, with more oxide staining.

Quartz is less common, up to 5%, embayed, fractured and sometimes strongly skeletal bipyramids. Up to 2mm. Otherwise, no difference to the lower samples. Again also part of recrystallisation of groundmass,lithics aud pumices, mostly as small patches of mosaic material.

Feldspars are more altered than the lower samples, still fractured subhedral rounded or euhedral crystals, most are partly sericitised sodic plag, common voids from cutting and polishing, common calcite replacement in with the sericite. About 8%, 0.1–4mm. Mafic here is more altered than both lower samples, again Trace to 1%. Also some goethite/hematite alteration/staining. Not really identifiable as having been biotite without the evidence from LF4M.

Matrix is still brownish, more hematite/goethite staining than both lower samples, felsitic in cpl, still good shard texture in ppl, with tightly packed, flattened shards, slightly better 'wrap around' textures, and fiamme are rare. Again, most are devitrified to felsitic style texture, but some are fibrous and pumice fiamme are either partly spherulitic or quartz-feldspar mosaic recrystallised.

Field Number	Formation:					
LC3 *	Divisadero Tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
286560	4947721	3	1	96		100
Final Rockname						
Crystal poor welded dacitic-rhyodacitic ignimbrite.						

Microscopic textures (LC3): Eutaxitic textured rock with wispy pumice lenses, large ash shards, crystal fragments and lithic fragments in a reddish stained felsitic matrix of devitrified ash material. No primary Quartz. Less pumice richthan lower levels.

Feldspars are subhedral, fragmental sodic plagioclase, often partly sericitised. Crystals are small, most around 1mm, about 3%. Section T a gives 16 degrees, so looks like albite. RI is also lower than mediumboth fast and slow, so probably albite. Some untwinned fragmental crystals with Very low RI may be K-spar, 2v 40-60, positive.

Lithic fragments are up to 6mm in thin section, but most are 1mm range,about 1%. Largest seen is also tuff/ignimbrite, devitrified and recrystallised to mosaic quartz. Smaller 1mm and less are rounded, oxidised andesitoid/dacitoid fragments.

Matrix is fine grained goethite/hematite red stained and devitrified ashy material, with larger flattened eutaxitic textured glass shards and pumice lenses, also devitrified and in some cases recrystallising into spherulitic or mosaic quartz/feldspar textures. Eutaxitic texture is well developed with sparse but good pumice lenses, wispy fragments, flattened cuspate shards, and 'wrap around' textures around lithics and crystals. Some void spaces have calcite fill, and some pumices also show alteration to fine grained sericite and calcite. Some fine subvertical fractures filled with sericite, quartz mosaic and calcite.

Field Number	Formation:					
CD12M *	Divisadero Tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
267771	4946000	1	1	98		100
Final Rockname						
Welded ignimbrite.						

Microscopic textures (CD12M): Middle sample is still Brown vitroclastic tuff/ignimbrite, well developed vitroclastic texture in matrix with flattening and devitrification of shards, crystal poor, but with lithics up to 6mm, pumices up to 2cm. Unlike the base, there are fine, narrow sub-horizontal fractures, cutting the fiamme texture at about 10 degrees, filled with mosaic quartz.

Crystals are still sparse, about 1%, and are either 0.5–2mm subhedral fractured and maybe zoned sodic plagioclase or occasional small cleavage flakes or 'booklets' of pleochroic green-brown biotite. Feldspar RI fast and slow are below mounting epoxy, probably Albite. Some crystals of plagioclase have sericitised cores. Biotite appears fresh.

Pumice fragments are still wisp-ended lensoidal fragments and partly flattened angular fragments, but some appear quite blocky and a little less flattened. Devitrification textures are as with the basal sample, with some showing felsitic and incoherent spherulites, some larger pumices with small, well developed spherulites and some with quartz/feldspar mosaic textures, and most show two or more of these textures. Spherulitic textures seem a little more common. Some pumices contain sodic plagioclase fragments.

Lithics are still angular or sub angular to rounded oxidised fragments of intermediate volcanic rocks or siliciclastic volcaniclastic sediments. Up to 5mm, but most sub 1mm. 1%

Matrix is brown-stained ash/glass shards in a felsitic brown material (showing remnants of finer shards.) Somewhat flattened and eutaxitic vitroclastic texture is well developed. Wrap-around textures are present around lithics and crystal fragments, and may be a little better developed than those in the basal sample. Individual shards have either felsitic or partial spherulitic devitrification and recrystallisation textures, and show up in both ppl and cpl. Some also show fine, cherty quartz mosaic textures.

Field Number	Formation:					
LF4M *	Divisadero Tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
272657	4938702	31	1	68		100
Final Rockname						
Mauve to brown lithic poor sintered or partly welded crystal rich rhyolitic tuff/ignimbrite.						

Microscopic textures (LF4M): Very similar to LF 4 B,Tuff or ignimbrite with embayed and skeletal quartz, altered feldspar and occasional lithic fragment in fine grained, felsitic devitrified brown matrix. Occasional pumice fiamme are difficult to tell apart from the matrix, although some have irregular spherulitic texture, and in this sample are a bit more porous.

Quartz is common, up to 10%, embayed, fractured and sometimes strongly skeletal bipyramids. Up to 2mm. Some crystals within pumices have nucleated spherulites during devitrification/cooling. Some quartz also as part of recrystallisation of groundmass, lithics and pumices, mostly as small patches of mosaic material. Mosaic recrystallisation of some fiamme more advanced than LF4B. Feldspars are about 20%, altered fractured subhedral rounded or euhedral crystals, most are partly sericitised sodic plag, with some epidote alteration also, and some calcite replacement in with the sericite. RI both fast and slow well below medium, so probably Albite and maybe some K-spar.

Mafic here is altered to similar opaques/calcite mix to that in LF4B, but has remnant brown biotite near edges of crystals, although little orno pleochroism. Trace to 1%. Also some goethite/hematite alteration/staining.

Lithics: trace to 1%, subangular tuffaceous fragments, 1mm or less.

Matrix is again brownish, felsitic in cpl, but has better preservedshard texture still visible in ppl, with tightly packed, flattened shards, but still without strong 'wrap around' texture, and fiamme are rare. Again, most are devitrified to felsitic style texture, but some are fibrous and pumice fiamme are either partly spherulitic or quartz-feldspar mosaic recrystallised.

Field Number	Formation:					
CD7M *	Divisadero Tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
267771	4946000	25	5	70		100
Final Rockname						
Well welded crystal rich devitrified core of vitric tuff.						

Microscopic textures (CD7M): As with basal sample, a fairly uniform fine grained vitric tuff, but with slightly more crystal and lithic fragments than the basal material,about 20%, remaining 80% devitrified glassy ash and pumice. Crystals are about 15%, lithics 3–5%, size ranges about 0.4mm to 4mm, avg sub1mm, but more larger 2-3mm feldspar than basal sample. Quartz and sodicplagioclase still most common, perhaps some k-spar.

Quartz is rounded, embayed and often fragmental bipyramids, up to 3mm. About 10%. Some embayments and voids contain devitrified glassy material.

Feldspar is about 15%, subhedral and euhedral crystals, often fractured, some glomeroporphyritic, up to 2mm. Alteration is common, usually slight murkiness of crystals, some incipient sericitisation. Sodic plag, albite, seems to dominate, same as basal sample.

Lithics less common, about 5%, up to 3mm and are slightly oxidised and devitrified angular fragments of tuff and ignimbrite.

Matrix is devitrifed ash shards, but vitroclastic texture is very faint, only just visible in ppl, otherwise matrix is grainy brown featureless material. In CPL, matrix is coarse cherty devitrified and recrystallisedfelsitic texture. This destruction of much shard texture may reflect greater welding effect, with shards sintering together such that their individual shapes are not preserved on devitrification, unlike the basal sample.

Field Number	Formation:					
CD7B *	Divisadero Tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
267771	4946000	10	3	87		100
Final Rockname						
Base of massive, rhyodacitic to Rhyolitic sillar or sintered tuff/ignimbrite.						

Microscopic textures (CD7B): Rock is a fairly uniform fine grained vitric tuff with about 15% crystal and lithic fragments, remaining 85% devitrified glassy ash and pumice. Crystals are about 10%, lithics 3-5%, size ranges about 0.4mm to 3mm, avg sub 1mm. Quartz and sodic plagioclase most common, perhaps some k-spar.

Quartz is rounded, embayed and often fragmental bipyramids, up to 3mm. About 3%. Some embayments and voids contain devitrified glassy material.

Feldspar is about 7%, subhedral and euhedral crystals, often fractured, some glomeroporphyritic, up to 2mm. Alteration is common, usually slight murkiness of crystals, some incipient sericitisation. Sodic plagioclase seems to dominate, ML: 15, 7, 17, 7.5, 10, looks like albite or oligoclase. 2v 80 ish, RI f&s below medium. Albite or Sodic Alkali Feldspar.

Lithics are about 3%, up to 1.5 or 2mm (hand spec.) and are dominatedby slightly oxidised and devitrified angular fragments of tuff and ignimbrite.

Matrix is devitrifed ash shards, retaining vitroclastic texture in ppl, but felsitic in Cpl. Larger fragments have semi spherulitic or radial devitrification along margins. Not particularly welded, but slightly flattened and devitrification crosses shard boundaries, so probably sintered or sillar welding. (NB, no strong column development inoutcrop.)

Field Number	Formation:					
LC1 *	Divisadero Tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
286560	4947721	10	8	82		100

Microscopic textures (LC1): Brown stained pyroclastic rock with moderate eutaxitic texture, sparse crystals and lithics, dominated by altered pumice fiamme and oxide stained ash matrix.

Rock is crystal poor, less than 10%, maybe less than 5%, but has about 15–20% 3–15mm partially flattened pumices, Oxidised lithic fragments about 5–8%, remaining about 70% red oxide stained shard textured and devitrified ashy matrix.

Pumice fiamme are large, lensoidal or wispy, up to 15mm in handspec. Vesicles can still be seen, as can perlitic fractures in the more compressed fiamme. Most are now altered to fine euhedral or mosaic feldspar and quartz in a matrix of cherty textured sericitic material.

Sparse sub 0.5mm feldspar crystals are sodic plagioclase, partly altered, murky, mostly euhedral but often fractured. RI would appear to indicate Albite. Secondary feldspar may occur in the mosaic material replacing pumices, as two minerals are evident by becke line test.

Primary igneous Quartz crystals are present in trace quantity only, although it is a common replacement of pumice fiamme, and also occurs as a vein filling in small vertical fractures running through the rock.

Field Number	Formation:					
F50 *	Divisadero Tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
284100	4870800	21	5	74		100
Final Rockname						
Rhyolitic tuff.						

Microscopic textures (F50): Tuff with subhedral and fragmental crystal fragments matrix supported ina devitrified felsitic textured ashy groundmass. Crystal fragments are quartz, embayed and zoned with cherty/murky cores, and sodicplagioclase, also minor k-spar and some muscovite and opaques perhap safter biotite. Secondary alteration includes hematite, leucoxene, fine grained chlorite and muscovite in groundmass and void spaces.

Quartz is around 10%, fractured and embayed crystal fragments,sometimes bipyramidal, and some with unusual striated/mottled cores, overgrown by clear quartz with embayement structures. Mostly 0.5–1mm,some unbroken crystals up to 3mm.

Plagioclase is about 10%, broken and fragmental subhedral to euhedralcrystals with albite-carslbad twinning and occasionally zoned. Some alteration to sericite and patchy or network alteration to K-spar. Albite twinning gives: 6, 5, 10, 28, 21, 8, 11, so about An40%, Andesine, but many crystals have angles and RI of more sodic compositions, and some crystals are rimmed with K-spar. Primary k-sparmay be present as crystals, but difficult to identify due to common fragments of plagioclase that have been partly or wholly replaced by network fine k-spar.

Biotite: Trace, altered to hematite and muscovite, about 1%, cleavage fragments.

Lithic fragments, 1-5%, rounded to subangnlar fragments of felsitictextured devitrified tuff or occasional andesitoid volcanic fragments,up to 3mm.

Pumice fiamme are not present, but devitrified or spherulitic glass fragments occur, with well developed vesicles and shard wall textures,about 2%, up to 3mm.

Groundmass is fine grained felsitic textured devitrified ashy material, with occasional ghosting of shard textures, some fine grained chlorite,and void filling of cherty quartz, secondary hematite, and also networks of fine muscovite micas, particularly around altered feldspar crystals. Some calcite also in voids. About 70% of rock with 4% voidspaces filled with epoxy or alteration products.

Field Number	Formation:					
CD9	Divisadero Tuff/Ig					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
267771	4946000	25	1	74		100
Final Rockname						
Vitric Tuff. This sample yielded Ar-Ar age on biotite of 138±4.9Ma, too old, probable excess Ar.						

Microscopic textures (CD9): Well preserved vitric tuff with about 20% crystal and lithic fragments in a matrix of devitrified glass shards with development of felsitic andoccasional spherulitic textures with some sericite replacing well defined vitroclastic shard textures.

Crystal fragments are about 20–25% of the total, comprising 10–15%broken subhedral and euhedral sodic plagioclase, RI fast and slow below epoxy, so probably sodic oligoclase to albite, and 3–4% subhedral quartz, plus 1% biotite cleavage flakes. Some feldspar crystals are partly altered to k-spar along fractures and cleavages, or have mildsericitic alteration, otherwise fresh. Biotite flakes are contorted and kink-folded around crystals and shards, possibly due to compactionand/or welding. Crystals are well sorted, between 0.5–1mm, rarely more than 1mm. Trace magnetite, altered to leucoxene.

Lithic fragments are rare, <1%, occasional red oxidised angular fragments of tuff.

Matrix is about 70–75% of total, comprised of well preserved vitroclastic shard texture with some flattening and wrap-around ofshards near crystals, with secondary felsitic and spherulitic devitrification textures, but some original glass remains. Some marginal sericite alteration of shards and pumice fragments occurs along rims and as void filling between shards, as well as occasional brown oxide staining near lithic or mafic fragments. Some voidfilling with greenish amorphous alteration.

Field Number	Formation:					
F25A	Divisadero tuff/sediment					
Utm East	Utm North	QF:	RF:	FF:		Subtotal:
287276	4872850					0
Final Rockname						
Well sorted thinly bedded and bioturbated tuffaceous siltstone. Zeolite facies						

Microscopic textures (F25A): Fine silty sediment with patches or nodules of bright green chlorite,dark isotropic low RI Analcime, and reddish orange hematite.

Calcite and analcime may occur together as void filling.

Occasional fine Chlorite pervasive through rock as void fill and alteration product.

Quartz occurs as fine angular grains of detrital volcanic quartz, aswell as recrystallisation product.

Bulk of rock is partly recrystallised, fine felsitic textured silt size material, presumably partly rexllised ash, with round patches of dark isotropic alteration, possibly to analcime. Also halos and patches of orange iron oxides and opaque iron oxides and perhaps manganese oxide.

Trace detrital minerals include occasional feldspar, biotite, as well as opaques.

No easily discernable glass shards, but the felsitic textures and zeolite alteration patches make this rock look like water laid finefelsic volcaniclastic material.

Field Number	Formation:					
F25B	Divisadero tuff/sediment					
Utm East	Utm North	QF:	RF:	FF:		Subtotal:
287276	4872850					0
Final Rockname						
Very well sorted tuffaceous fine siltsone. Zeolite facies						

Microscopic textures (F25B): Very fine siltstone, with spots of opaque hematite or similar oxides,with some fractures rimmed by alteration haloes and dendritic oxide growths.

Silt is fairly featureless fine silt size grains with strong lattice and shape orientation parallel to bedding, with semi opaque orange iron oxides from 0.1–0.5mm. Silt is partlly isotropic, possibly from analcime occuring as alteration of ash grains, but also has an astomosing fine colourless or slightly greenish bedding parallel phyllosilicate or sericitic alteration, possibly fine muscovite, length slow, straight-ish extinction but difficult to pick individual grains. RI of fine silty material and its alterations well below epoxy, and fairly murky, so possibly clays of some sort present as well. Greenish grains may be chlorite, also with bedding parallel spo/lpo.

Isotropic analcime occurs as void and vein filling and probably within patchy isotropic areas of groundmass silt.

Trace quartz/adularia growth in fractures, and relict very fine grains of detrital quartz/feldspar probably present in silt as detritals.

Field Number	Formation:					
F63	Divisadero tuff/sediment					
Utm East	Utm North	QF:	RF:	FF:		Subtotal:
280690	4868900					0
Final Rockname						
Moderately sorted angular to sub angular tuffaceous coarse sandstone.						

Microscopic textures (F63): Tuffaceous medium to coarse sandy rock, with:
5% broken volcanic quartz fragments, 5% secondary opaque alterationoxides, 25% altered sodic plagioclase feldspars replaced by calcite andsericite, 25% rock fragments, mainly felsitic or quartz mosaic textured rhyolitoids, as well as oxidised intermediate volcanics, 30–40% ashy matrix and crushed and altered pumice, showing felsiticre crystallisation and chlorite and sericitic mica alteration, with some coarsened up to 0.5mm muscovite grains.

Field Number	Formation:					
F30A	Divisadero tuff/sediment					
Utm East	Utm North	QF:	RF:	FF:		Subtotal:
285520	4870960					0
Final Rockname						
Normal and reverse Graded, moderately sorted angular to subangular fine sandy to coarse silty tuffaceous sandstone.						

Microscopic textures (F30A): Graded, Fine sand to coarse silty, moderately sorted angular tosubangular tuffaceous sandstone.

Rock is graded sandstone with quartz, plag, rockfragments anddevitrified glass, cemented with calcite and chlorite and argillaceous material, plus by effects of glass devitrification.

Grains are laminated and graded both normally and reverse, with very low angle crossbedding and mechanical sorting of opaque rich laminations on some crossbeds.

Chlorite cement is moderate green pleochroic, with platy, anastomosing grains between detrital minerals. Moderate shape and lattice orientation parallel to bedding.

Calcite cement is sparse, more common as void filling and alteration of feldspars.

Feldspars are mostly plagioclase, fairly calcic from RI, but fairly full range of compositions.

Rock fragments are: devitrified rhyolitics, spherulitic rhyolitics, felsitic rhyolitics, oxidised intermediate to mafic andesitoids.

Glass shards are common, devitrified to felsitic texture or replaced by sericitic and chloritic material. Trace detrital biotite, common iron oxides, etc, many opaques altered to leucoxene.

Proportions about Quartz/Feldspar 20/30, Rock frags 15–20%, Devit glassshards 20%, Chlorite 8%, Clays/ calcite opaques, 2%.

A.4.2 Andesitic Lavas

Field Number		Formation:					
F35		Divisadero Andesitoid					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
286700	4872150		2	10	55	0	67
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
3				20			
Other components:		Others:	Total:				
Alteration products		10	100				
Final Rockname							
Andesitic or basaltic andesitic lava.							

Microscopic textures (F35): Porphyritic rock with euhedral plagioclase feldspar phenocrysts and occasional pyroxenes in a groundmass of pilotaxitic feldspar laths and intergranular mafics. Alteration includes chlorite, celadonite,sericite, etc.

Plagioclase is about 15–20%, 1–4mm -euhedral sodic plagioclase,sometimes sieve textured, sometimes glomeroporphyritic, albite and carlsbad twinned, murky and slightly sericitised, some cores replaced by chlorite, while other crystals have patches of bright green celadonite,or fine fibrous yellow length fast material. Too altered for ML or similar method. RI against epoxy has both fast and slow below, so probably Albitised.

Pyroxene is sparse, subhedral crystals, about 3mm, less than 1% as phenocrysts. 2v is low, crystals are slightly green/yellow in ppl,possibly subcalcic augite.

Groundmass is pilotaxitic textured plagioclase microphenocrysts, about30-35%, <0.1mm, ML of 23, 17, 26, 22, 24, 7, 15, about An%35-6,Andesine , 20% opaque magnetite, 2–3% quartz and clinopyroxene, apatite, maybe minor aenigmatite. Also about 10% alteration products, including chlorite and hematite after pyroxene, bright green celadonite, calcite and perhaps trace green amphibole, and about 5-10% anhedral, low RI moderate 2v ?k-spar.

Field Number	Formation:					
S4	Divisadero Conglomerate					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
280075	4879433					0
Final Rockname						
Pyroclastic agglomerate or reworked pyroclastic agglomerate of trachy basaltic to quartz trachytic composition.						

Microscopic textures (S4): Coarsely laminated but well sorted rock of angular to sub-angular small pebble to grauule size clasts or pyroclasts of vesicular brown oxidised basaltoid trachy-basaltoid to trachy andesite. Rock is clast supported, with a sparse matrix of calcite. Some non mafic clasts occur, with occasional small fragments of rhyolitoid material seen in hand specimen and one felsitic fragment seen in thin section, plus occasional free crystal of bipyramidal quartz. Alteration is pervasive, with much secondary hematite and similar iron oxides staining all clasts brown to red-brown opaque. Calcite is present between clasts and also replaces many feldspars and fills vesicles.

Clasts are almost all uniformly oxidised, with groundmass dominated by semi-opaque reddish hematite, plus some chlorite and clays, but still display porphyritic texture with pilotaxitic feldspar laths within a groundmass of smaller pilotaxitic feldspars and intergranular oxidised mafics and opaques. Feldspars may have been sodic plagioclase, now albitised? with some swallowtail textures, esp. in microphenocrysts, and some larger crystals (.5mm) have outer rims of ?anorthoclase. Some clasts appear to have quartz present as a primary mineral. Feldspar RIof remuant crystals is well below medium, both fast and slow, so Albiteor K-spar.

Field Number		Formation:					
CM1		Divisadero Dacitic Breccia					
Utm East	Utm North		Q:	A:	P:	F	Subtotal:
729990	4917220		20	10	55	0	85
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
8				7			
Other components:		Others:	Total:				
			100				
Final Rockname							
Dacitic Breccia/block and ash tuff.							

Microscopic textures (CM1): Altered dacitic rock with porphyritic texture of sodic plagioclase,clumps of glomeroporphyritic plag/opaque/pyroxene, minor secondary quartz, in a felsitic groundmass with some pilotaxitic textures and incipient mosaic quartz/feldspar recrystallisation. Common secondary iron staining or fine oxidation products.

Feldspars are altered sodic plagioclase, euhedral and glomeroporphyritic, sometimes with magnetite and greenish pyroxene. 0.5–5mm. Clayey and opaque in places, with some calcite replacement. RI well below epoxy, so Albite. About 30%

Opaques are common, fine blocky disseminated material in groundmass, as well as blocky phenocrysts with glomeroporphs of plag/pyxne. Mostly magnetite, with associated hematite alteration. Apatite tends to occurwith the opaques. About 7%

Pyroxene is partially altered, blocky euhedral crystals up to 2mm, slightly greenish and altered to opaques and chlorite in some crystals. Occurs with plagioclase and magnetite in glomeroporphyritic patches. Small positive 2v šubcalcic augite. 8%

Groundmass is 55% of rock, fine grained felsitic material, partially mosaic recrystallised, with occasional secondary quartz void filling and faint pilotaxitic texture of sodic plagioclase microphenocrysts. Estimate about 25% sodic plag, 20 quartz and 10% altered-kspar in incipient mosaic recrystallisation of felsitic material.

A.5 Cerro Pico Rojo Rhyolite Dome

Field Number	Formation:					
F51B	Cerro Pico Rojo Rhyolite					
Utm East	Utm North	CF:	RF:	V:		Subtotal:
283020	4873950	2	5	93		100
Final Rockname						
Peralkaline rhyolitic pumiceous tuff.						

Microscopic textures (F51B): Crystal poor pumiceous tuff, consisting of irregular partly flattened juvenile rhyolitoid and poorly vesicular pumice clasts in a grey felsitic matrix of devitrifed ash, with traces of glass shard texture. Lithic fragments are sparse, but do include oxidised fragments of what appears to be Divisadero or Ibáñez style quartz/feldspar crystal bearing ignimbrite. Matrix and pumices are oxide stained with hematite, and some vapour phase crystallisation appears to have taken place in some pumice vesicles. Pumices are yellowish in ppl, and have devitrified into mosaic quartz and feldspar, although microlites can still be seen under high power. Any mafic phase in the matrix has been oxidised to fine granular and acicular hematite and goethite, but some pumices have sparse, slightly altered blue-green pleochroic microphenocrysts which may be sodic amphibole.

Approx 1–2% Crystal fragments (mostly quartz), 5% lithics, 93% vitric ash and pumices.

Field Number		Formation:					
GA5 *		Cerro Pico Rojo Rhyolite					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
285530	4873588		55	40	0	0	95
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
				5			
Other components:		Others:	Total:				
			100				
Final Rockname							
Rhyolitic Lava (Peralkaline rhyolite.)							

Microscopic textures (GA5): Sparsely porphyritic flowbanded felsitic rhyolite, with about 20% subhedral bipyramidal 0.4–1mm quartz phenocrysts, sometimes with skeletal textures, and (5%) occasional euhedral K-spar phenocrysts up to 2–3mm, often altered or ripped from section by saw. Groundmass is brownish, flowbanded felsitic material with quartz microphenocrysts and occasional patches of mosaic quartz recrystallisation. Common disseminated opaque or semi opaque hematite staining and void fill, and brownish alteration of mafics. Minor occurrence of bright green celadonite as void filling. Groundmass is 75% of rock ,about 5% altered oxidised mafics, opaques and secondary celadonite/chlorite, remainder 35% each quartz and k-spar in felsitic texture.

Field Number	Formation:					
GA7 *	Cerro Pico Rojo Rhyolite					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
285020	4873240					0
Final Rockname						
Aphanitic rhyolitic lava. (Peralkaline Rhyolite)						

Microscopic textures (GA7): Very fine grained aphanitic flowbanded felsitic rhyolite, with only one 1m phenocryst of euhedral sanidine, in a groundmass of flowbanded felsitic material with occasional (10–15% each) microphenocrysts of quartz and k-feldspar, with some pilotaxitic texture to feldspar grains. Much of felsitic material shows incipient mosaic recrystallisation to fine grained quartz-feldspar mosaic. Too fine for any reliable QAPF, normative figures are about Q34, A30, P32. Mafics are sparse, fine brownish oxidised material in groundmass, but some patches of granular mafics show blue-green colour, possibly remnant sodic amphibole.

Field Number		Formation:					
F53		Cerro Pico Rojo Rhyolite					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
283570	4873620		41	56	0	0	97
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
				3			
Other components:		Others:	Total:				
			100				
Final Rockname							
Rhyolitic Lava. (Peralkaline Rhyolite)							

Microscopic textures (F53): Large euhedral to subhedral quartz and k-spar phenocrysts in a felsitic groundmass. Common disseminated iron oxide patches and stains.

Quartz phenocrysts are occasional rounded and embayed beta quartz bipyramids, usually 1–3mm, subhedral. 5%.

K-feldspar phenocrysts are common, about 20%, subhedral to anhedral polcrystalline clusters/glomeroporphs. Very low RI, strong negative releif, small -ve 2v, probably Sanidine. Polycrystalline sanidine crystals have granitic textures with subhedral crystal boundaries, so are interpreted as cognate xenoliths. Some crystals are slightly perthitic.

Groundmass is 75% of rock, felsitic material with patches of mosaic quartz recrystallisation and occasional sanidine microphenocrysts.

Unlike other samples, no remaining blue/green amphibole, but small patches of brownish alteration product may be pseudomorphs of any original sodic amphibole. Opaque iron oxides and brownish alteration products about 3%, so approx 36% each kspar and quartz from felsitic material. Spherulitic texture visible in hand specimen has been mostly removed by recrystallisation.

Field Number	Formation:					
S8	Cerro Pico Rojo Rhyolite					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
284500	4878500					0
Final Rockname						
Peralkaline rhyolitic lava, probably similar to C. Pico Rojo group.						

Microscopic textures (S8): Sparsely porphyritic flowbanded rock with phenocrysts of K-feldspar in a flowbanded and well recrystallised quartz-k-spar mosaic groundmass, with some shape and lattice preferred orientation of mosaic crystals. Patches of semi-opaque red hematite and other oxides occur parallel to flowbanding. Flowbanding appears to exert some control on shape and lattice preferred orientation of recrystallised groundmass, perhaps reflecting some original pilotaxitic groundmass feldspar.

Feldspar phenocrysts are euhedral or broken subhedral crystals, most about 1mm or less, 3-5%. Flowbanding shows some 'wrap around' textures with respect to the crystals. 2v is small to moderate negative biaxial. Oap appears to be perpendicular to 010, so probably Sanidine.

Groundmass is mosaic rexllised quartz and k-feldspar, with some clear mosaic quartz also grown in voids/lithophysae. Under high power remnant microlites of k-spar can be seeu to have well developed flow aligumeut which has been partially destroyed/modified to poikilomosaic texture by recrystallisation to mosaic material, but has imparted prefferred orientation on that material, both lattice and shape. Fine dissemnated blue-green pleochroic amphibole, probably Riebeckite, is present in trace amounts in groundmass. Occasional hematite rimmed altered blue green amphibole occurs as microphenocrysts up to 0.1mm.

Too fine for accurate QAPF, Normative composition about: Q32, A24, P26.

Field Number		Formation:					
F51A		Cerro Pico Rojo Rhyolite					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
283020	4873590		51	46	0	0	97
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
		3					
Other components:		Others:	Total:				
			100				
Final Rockname							
Flowbanded and autobrecciated peralkaline rhyolite lava.							

Microscopic textures (F51A): Aphanitic flowbanded rhyolitic rock with almost no phenocrysts except small subhedral quartz microphenocrysts, dominated by partly recrystallised felsitic texture with felsitic k-spar-quartz mix and some zones of coarsened anhedral rexllised quartz occuring along flowbandiug. Within felsitic matrix, small blue-green pleochroic microphenocrysts occur, maybe arfvedsonite/riebeckite type.

Occurrence of sodic amphibole concurs with chemistry which shows this rock to be Peralkaline. Quartz microphenocrysts about 5%, Sodic amphibole 3%, felsitic material 92% (=46% each q and a)

Field Number	Formation:					
S7 *	Cerro Pico Rojo Rhyolite					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
284325	4878510					0
Final Rockname						
Alkaline or peralkaline rhyolite, probably related to C. Pico Rojo dome complex.						

Microscopic textures (S7): Sparsely porphyritic rock with small k-feldspar phenocrysts and occasional quartz in a groundmass of felsitic material partly mosaic recrystallised to quartz and k-feldspar.

Feldspar phenocrysts are low birefringence, euhedral to subhedral crystals up to 1mm, about 3%. Occasionally carlsbad twinned, small 2v indicates Sanidine.

Small quartz microphenocrysts occur, subhedral, less than 0.2mm, often clear mosaic quartz, perhaps secondary void filling.

Groundmass is remnant k-feldspar microlites in very fine pilotaxitic texture, now replaced by complexly sutured mosaic of quartz and k feldspar. Mafic phase within groundmass is strongly blue green pleochroic amphibole, probably Riebeckite, occasionally present as microphenocrysts up to 0.2mm.

Too fine grained for accurate QAPF. Normative composition about: Q33, A25 P26.

Field Number	Formation:					
S2 *	Cerro Pico Rojo Rhyolite					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
282216	4874163					0
Final Rockname						
Devitrified red rhyolitic Obsidian.						

Microscopic textures (S2): Flowbanded and red-stained obsidian, with sparse feldspar crystals and some small spherulites.

Feldspars are small, <5%, 1-1.5mm or less, euhedral, appear to be albite, (albite twins, faint zoning, and RI strongly below medium) but untwinned crystals could be K-spar. Some are glomeroporphyritic and albite twinned, others are small, euhedral stubby crystals with low RI and no twinning or carlsbad twinning. From 2v, small crystals would appear to be sanidine. (v. small negative 2v.)

Opaques are small round structures, possibly goethite/hematite filled vesicles? Other cavities, occasionally at the core of perlitic crack structures, are filled with bright green chlorite and perhaps some celadonite.

Glass matrix is pale brown to orange-red, with some devitrified bands gone entirely to spherulites, but within the red glass, spherulites are small and sparse, but elongate devitrification bands and clusters occur, along flowbanding as elongate spherulite like clusters of crystals. Perlitic cracking is common but non pervasive. Red staining also occurs along cracks cutting unstaiued spherulitic bands, so perhaps it is a secondary oxidation effect,maybe Hematite staining. Bright green celadonite occurs as void filling material.

A.6 Plateau Basalts

Field Number		Formation:					
S10B *		Plateau Basaltoid					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
285500	4876800		2	5	50	0	57
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
16			5	12			10
Other components:		Others:	Total:				
			100				
Final Rockname							
Basaltic to andesitic lava. Chemically basaltic to trachybasaltic lava.							

Microscopic textures (S10B):

Porphyritic rock with phenocrysts of Plagioclase, Pyroxene, and a red to brown altered mafic that may have been Olivine, but some pseudomorphs have pyroxene shapes, and magnetite phenocrysts, in a groundmass of intergranular plagioclase, clinopyroxene and magnetite. Some fine-grained, granular xenoliths of pyroxene and plagioclase.

Plagioclase is subhedral to anhedral phenocrysts up to 0.5–3mm. Often glomeroporphryitic and zoned with an outer sieve textured rim, and often with inclusions of augite or altered amorphous green material. Some polycrystalline zenoliths with anhedral plagioclase and pyroxene in granoblastic texture occur. Plagioclase phenocryst Rl has both fast and slow slightly and moderatly above epoxy, while poor albite-carlsbad twin gives 8, 33, about An55%, Sodic Labradorite. Large phenocrysts are about 3–5% of rock.

Pyroxenes are Clinopyroxene, augite group, slightly brownish, subhedral to euhedral crystals, sometimes altered to chlorite. 0.1mm groundmass to .5–2mm phenocrysts, low 2v, 25 ish, euhedral to anhedral, sometimes rounded or twinned, sometimes present as inclusions within sieve textured plagioclase and with alteration to amorphous or fibrous green chlorite or brownish iron oxides. Also common in groundmass as microphenocrysts and as granular crystals within cognate xenoliths. About 16%. Other mafic is orange-yellow iddingsitised olivine pseudomorphs, either amorphous or slightly pleochroic with single cleavage like biotite. Sections with cleavage show straight extinction, but grade into amorphous material Some have yellow-green ?chlorite rim. From some crystals with double pointed shape, these pseudomorphs were probably olivine. About 10%.

Groundmass is subhedral to euhedral 0.1–0.5mm plagioclase feldspar in intergranular texture about granular magnetite, patches of brown altered olvine and interstitial chlorite 5% and small clinopyroxenes. Some pilotaxitic texture, maybe some glass. Section perp-a on plagioclase gives 34 degrees, About An55–58%, Sodic Labradorite. About 45% of rock. Magnetite and opaques, 10–12%, 1–2% interstitial quartz and 4–5% interstital k-spar.

Field Number		Formation:					
S9A *		Plateau Basaltoid					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
284600	4877575		0	2	70	0	72
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
15				10			3
Other components:		Others:	Total:				
			100				
Final Rockname							
Basaltic or Basaltic andesitic Lava. Chemically basaltic to trachybasaltic.							

Microscopic textures (S9A):

Sparsely porphyritic rock, with phenocrysts of plagioclase, pyroxene and another altered mafic mineral in a pilotaxitic groundmass of feldspar microphenocrysts and intergranular opaques and altered mafics. Occasional xenocryst of quartz with reaction rims.

Larger plagioclase phenocrysts are 0.5–3mm euhedral to subhedral crystals, some fractured, most carlsbad-albite twinned, some with complex sector twins and pericline twins. Zoning is common, oscillatory normal. Some sieve textures too. Not enough crystals for ML, RI fast and slow is significantly above medium, while section Ta gives core 43, rim 36, so zoning is about An78 at core and 65 at rim, Bytownite to Labradorite. Albite-Carlsbad gives 30, 6, about An60%.

Pyroxenes are generally euhedral to subhedral brownish 0.5–1mm Augite group clinopyroxenes, some altered to brownish semi-opaqe material, probably hematite.

Olivine may be present as brown or red brown murky iddingsitised or otherwise altered pseudomorphs, with sparse 1mm and less brown lozenge shaped pseudomorphs replaced by brown murky iddingsite and also opaque minerals and calcite.

Groundmass plagioclase microphenocrysts are euhedral laths, sometimes with slight swallowtail texture. Albite-Carlsbad on microphenocrysts gives 30, 3, about An68%, Labradorite. Intergranular opaque magnetite, cpyroxene and altered clinopyroxene occur, together with what may be minor amounts of anhedral interstitial k-spar. Altered material seems to be pseudomorphing pyroxene, and is semi opaque green-brown material, sometimes platy but non pleochroic.

This rock appears significantly more feldspathic than the S10 Sample, about 70% plagioclase, 10% opaques, 15% Clinopyroxene and altered pyroxene, 3% altered olivine and trace to 2% k-spar.

Field Number		Formation:					
S10A *		Plateau Basaltoid					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
85500	4876800		0	5	45	0	50
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
28				15		5	2
Other components:		Others:	Total:				
			100				
Final Rockname							
Basaltic to basaltic andesitic lava. Chemically basaltic to trachy-basaltic.							

Microscopic textures (S10A):

Note: Section is somewhat saw-scarred. Porphyritic rock with phenocrysts of Plagioclase, Pyroxene, and a red to brown altered mafic that may have been Olivine, but some pseudomorphs have pyroxene shapes, and magnetite phenocrysts, in a groundmass of intergranular plagioclase, clinopyroxene and magnetite. Some fine-grained, granular xenoliths of pyroxene and plagioclase.

Plagioclase phenocrysts are about 20%, euhedral to subhedral, larger phenocrysts up to 3–4mm. Oscillatory zoning and sieve textures are fairly common, and some crystals have inclusions of pyroxene, magnetite and green chloritic alteration products within the sieve textures. Some crystals are glomeroporphyritic, again with much sieve texture and inclusions, especially in cores of some crystals. Albite Carlsbad for larger phenocryst gives: 10, 36.5, about An68, Calcic Labradorite.

Pyroxene phenocrysts are Clinopyroxene, augite group, slightly brownish, subhedral, sometimes altered to chlorite. About 8%, 0.5-2mm, euhedral to anhedral, sometimes rounded or twinned, sometimes present as inclusions within plagioclase. Alteration is either to amorphous or fibrous green chlorite or brownish iron oxides. Also common in groundmass as microphenocrysts and as granular crystals within cognate xenoliths. Unlike the S3 and S6 samples, no appreciable orthopyroxene.

Other mafic is orange-yellow pseudomorphs, either amorphous or slightly pleochroic with single cleavage. Sections with cleavage show straight extinction, but grade into amorphous material Some have yellow-green ?chlorite rim. Probably iddingsite after olivine, up to about 2%.

Groundmass is about 75% of rock, with 25% subhedral pilotaxitic plagioclase feldspar in intergranular texture with granular magnetite 15% and small granular brown clinopyroxenes 20% and brown pleochroic biotite (5%) microphenocrysts, and about 5% anhedral interstitial low RI k-spar. Some pilotaxitic texture. Plagioclase microphenocryst ML: 8.5, 35, 21, 26, 33, 8, 23.5, About An 60% Labradorite, but smaller phenocrysts seem more sodic, perhaps down to An 30 or 40%.

A.7 Minor Intrusive Rocks

A.7.1 Undersaturated Basaltic Minor Intrusive Rocks

Field Number		Formation:					
F45 *		Mugearitic Basalt cutting Divisadero					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
82860	4868900		0	15	45	2	62
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
15				5			8
Other components:		Others:	Total:				
Glass		10	100				
Final Rockname							
Picritic olivine basalt, chemically plots as basanitic or mugearritic rock, normative olvine well sub 10%, so Mugearitic basalt.							

Microscopic textures (F45):

Porphyritic rock with phenocrysts of altered glomeroporphyritic olivine, pinkish augite, in a groundmass of intergranular plagioclase microphenocrysts and magnetite, fine pyroxenes and brown altered glass, together with brown biotite, alteration products, etc.

Olivine is euhedral, up to 2-3mm, 8%, glomeroporphyritic, and uniformly altered to green or brownish bowlingite/iddingsite, or replaced with calcite, quartz and chloritic material.

Plagioclase is about 45%, as microphenocrysts in groundmass, subhedral to euhedral, <1mm, sometimes swallowtailed, highest ML readings 37, An65%, Calcic Labradorite.

Pyroxene is large euhedral brown to pinkish crystals, up to 3mm, about 5%, 2v small, about 25. Looks like a fairly titanian augite. Some alteration to fibrous green or brown uralite/chlorite and calcite.

Round patches occur, filled with calcite, and low RI pseudo isotropic zeolite, sometimes faintly twinned, probably analcime or wairakite. These may be pseudomorphs of nepheline, about 1–2%.

Groundmass is 5% opaques, 10% altered brown pyroxenes, 45% plagioclase microphenocrysts and about 10% brown murky devitrifed glass with fine black microlites and brown biotite (common, brown pleochroic, straight extinction and length slow.) K-spar may be present in trace amounts, but cannot be easily estimated, Normative value is approx 15%.

Field Number		Formation:					
F11 *		Mugearitic Basalt cutting Ibáñez					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
288173	4869185		0	10	60	5	75
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
15		6					4
Other components:		Others:	Total:				
			100				
Final Rockname							
Nepheline Mugearite Sill.							

Microscopic textures (F11):

Porphyritic rock, with phenocrysts of Plagioclase, Augite, Nepheline, and occasional Kaersutite hornblende in a matrix of intergranular plagioclase, pyroxene and opaques. Trace altered olivine.

Pyroxenes 15%, 0.5–3mm, brown or greenish altered, 2v positive, small to moderate, probably titanian augite.

Olivine is present as occasional 10-15mm megacrysts in hand specimen, but only 3–4% subhedral slightly green phenocrysts up to 1–1.5mm in thin section, often altered to iddingsite.

Occasional subhedral phenocrysts of dark red-brown pleochroic hornblende, probably kaersutite. 0.5–1mm, 1% or less.

Plagioclase phenocrysts are 10% large 1–3mm, rounded or skeletal subhedral and euhedral phenocrysts with some sieve texturing and zoning, often with altered calcic cores, and groundmass feldspars are subhedral .2–0.5mm laths (about 50%), more calcic than An 20 by RI against medium, and groundmass carlsbad-albite twin gives 10 ,36, about An 66%, while large phenocrysts give ML readings of about 32 max, An 45%. So Andesine phenocrysts, up to Labradorite in the groundmass.

Nepheline is present as rounded phenocrysts, up to 0.5mm, although rare. Up to 5%.

Analcime zeolite occurs with calcite in vesicles.

Groundmass is mainly plagioclase feldspar, maybe 10% anhedral low RI k-spar interstitial to mafics and plagioclase, with intergranular augite and fine aggregates of brown granular or fibrous biotite, 10% in groundmass, maybe fine grained brown hornblende and some pyroxenes. Chlorite present as alteration.

Approx QAPF makes this a Mugearite, perhaps mugearitic feldspathoid bearing basalt, but chemistry is Mugearite, too.

A.7.2 Basaltic, Basaltic andesitic, Trachybasaltic/andesitic and Andesitic Minor Intrusive Rocks

Field Number		Formation:					
WI30 *		Andesite Intrusive cutting Ibáñez					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
271070	4859298		10	3	65	0	78
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
		12	5	5			
Other components:		Others:	Total:				
			100				
Final Rockname							
Hypabyssal andesitic intrusive.							

Microscopic textures (WI30):

Medium grained, almost microgranitic plagioclase/hornblende rock, porphyritic with phenocrysts of reaction rimmed hornblende in a groundmass of euhedral and subhedral granular plagioclase phenocrysts and microphenocrysts with interstitial anhedral quartz, chloritised mafics and opaques.

Plagioclase phenocrysts are zoned, occasionally sieve textured, and have patchy replacement by k-spar, and may have thin outer rims of k-spar. Section Ta gives core 42, rim 33, about An80% down to An55%, Bytownite to sodic Labradorite. Some fine sericite replacement occurs, especially in cores. Smaller phenocrysts with Albite Carlsbad are 15, 35, about An 60%, Labradorite. Large zoned phenocrysts are 1-2mm, smaller phenocrysts are subhedral 0.1–0.3mm. Plagioclase about 60–65% of rock.

Hornblende phenocrysts are pleochroic green to green brown, subhedral 1–6 mm crystals with well developed reaction rims of opaque minerals and murky brown or green granular mineral. About 12%.

Altered/chloritised mafics in groundmass: anhedral, interstitial to plagioclase, fibrous or cherty pleochroic green material probably uralitised amphibole, about 5%.

Quartz, small subhedral microphenocrysts or anhedral interstitial material in groundmass. About 10%.

Opaques are subhedral to euhedral blocky microphenocrysts and groundmass intergranular magnetite, and also some in alteration rims of amphibole. 5%

Trace k-spar as rims/alteration to plag, also perhaps minor interstitial k-spar in g/mass. 1–3% max.

Field Number		Formation:					
F10 *		Andesite Intrusive cutting Ibáñez					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
288230	4868535		15	5	55	0	75
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
			15	8			
Other components:		Others:	Total:				
Cristobalite		2	100				
Final Rockname							
Altered Andesite Sill.							

Microscopic textures (F10): Even grained rock, aphanitic with sparse large 2–3mm plagioclase phenocrysts in a groundmass of 0.5–1mm subhedral plagioclase microphenocrysts and anhedral interstitial quartz, with intergranular opaques and chloritised mafics. Common secondary calcite and chlorite.

Plagioclase phenocrysts and microphenocrysts are altered and often partly replaced by calcite, some sericite. ML on remnant twins gives: 16, 7, 15, 19, and RI is fast below and slow just below epoxy, so probably Albite, rather than Oligoclase. Most grains are patchy, altered and are probably albitised. 55%.

Calcite replaces patches of feldspar and is common in the groundmass. Chlorite/calcite occur in oblong pseudomorphs of mafic minerals, or as small round patches. Chlorite is platy, radial or chaotic clusters. About 10-15%.

Opaques are granular euhedral and subhedral blocky magnetite phenocrysts up to 0.5mm, and also microphenocrysts in groundmass, 8%. Some apatite associated with opaques. Some alteration to leucoxene.

Original texture would have been sparsely porphyritic plagioclase lath network with intergranular mafics and opaques. Feldspar texture still remains, but calcite and chlorite and sericite have replaced much of the original minerals.

Anhedral quartz occurs as interstitial material to plagioclase groundmass phenocrysts, perhaps up to 15%, also found with calcite in filled cavities, with euhedral terminations, and some cristobalite also occurs in cavities, 2%. Some grains show slight granophyric edge textures, with trace murky low RI k-spar intergrown with quartz, so 1-5% k-spar, difficult to estimate.

Field Number		Formation:					
F1 *		Andesite Intrusive cutting Ibáñez					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
288071	4866299		10	2	75	0	87
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
			7	6			
Other components:		Others:	Total:				
			100				
Final Rockname							
Andesitic Sill.							

Microscopic textures (F1): Phenocrysts of glomeroporphyritic, albitised? Plagioclase occur. Sparse. Some replacement of feldspars with calcite/sericite. Groundmass has blocky opaque magnetite, and altered feldspar laths, in pilotaxitic texture.

Sparse large Sodic plagioclase phenocrysts occur, about 2–3%, altered and sericitised. Euhedral and glomeroporphyritic. ML method not feasible, as twins are sparse and altered, but looks like Albite/Oligoclase, with RI indicating Albite.

Groundmass feldspar lath RI is below both w Quartz and glue. Some ?Anorthoclase (1–2%, trace, but mainly groundmass feldspar laths are fine albite, ML gives angles of 5–10, RI below epoxy. Albite is 70–75% of rock.

Also microphenocrysts of Quartz, 5–10%, 0.1–0.2mm, anhedral small grains and perhaps green uraltised or chloritised mafic 3–5%, in groundmass, altering to chlorite. Magnetite, quartz and green minerals (?Amph/chlorite) are intergranular to feldspar laths.

Chlorite alteration: 1–2%, 0.1–0.2mm, altering amphibole or pxne in gmass, also some larger patches with the Albite.

Other minerals: Leucoxene after magnetite, common calcite as void filling or alteration of plagioclase. Possibly trace Tridymite in g/mass. Magnetite and other opaques, 5–6%, in groundmass.

Andesite. Groundmass seems to have more albite than k-spar. Chemistry gives high end of TAS andesite field, close to Tr-Andesite.

Field Number		Formation:					
L17B *		Andesite Intrusive cutting Ibáñez					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
284860	4859830		10	5	65	0	80
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
5		5		10			
Other components:		Others:	Total:				
			100				
Final Rockname							
Andesitic minor Intrusive.							

Microscopic textures (L17B): Porphyritic rock with euhedral-subhedral augitic pyroxenes, with some reaction rims. Entirely altered hornblende group amphiboles, pseudomorphed by opaques. Groundmass of tabular, pilotaxitic feldspars. Some alteration patches/recrystallisation of groundmass into mozaics of quartz,feldspar. Trace calcite and euhedral quartz as void filling materials. Trace Epidote as alteration product of mafic minerals, with calcite.

Pyroxene is colourless, subhedral-euhedral, 0.5–2mm, 5% +ve 2v about 40, probably augite, possibly towards the diopside end. Sometimes glomeroporphyritic, and sometimes altered to chlorite and opaques at the rim.

Hornblendes are sparse, subhedral green brown phenocrysts, usually entirely altered, elongate pseudomorphs with opaques at rim, chlorite at core, perhaps also epidote/clinozoisite. 2%.

Groundmass is 90% of rock, mainly pilotaxitic tabular plagioclase laths, altered and sericitised, with interstitial quartz and intergranular opaques — magnetite, and patches of greenish and brownish mafics — chlorite altered. About 60–65% plag, too altered to identify by extinction angle, maybe 10% quartz, 3% granular brownish small pyriboles,10% opaques, maybe trace to 5% interstitial k-spar but difficult to tell. Some void filling of calcite and quartz.

Field Number		Formation:					
WI46B *		Andesite Intrusive cutting Ibáñez					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
272650	4858230		15	5	55	0	75
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
13				5			
Other components:		Others:	Total:				
Glass/calcite etc		7	100				
Final Rockname							
Andesitic dike cutting Puerto Rey Dome complex.							

Microscopic textures (WI46B): Porphyritic volcanic rock, with phenocryst phases of glomeroporphyritic plagioclase and altered green mafics in a groundmass of plagioclase microphenocrysts, opaques and dark brown volcanic glass. Common secondary calcite and chlorite as alteration products and void filling.

Plagioclase phenocrysts are 0.2 to 2mm, euhedral, 25%. Oscillatory zoning present, occasionally glomeroporphyritic. Calcic cores have been sericitised, with some calcite and epidote replacement. On larger phenocrysts, Section Perp. a gives: 37, gives An% 60: Carlsbad Albite, 18, 32, gives An% 55 ⟶ Labradorite

Mafic mineral: Blocky, euhedral and subhedral 1-2mm crystals entirely replaced by bright green chlorite, perhaps with some uralite. Shape suggests altered clinopyroxenes. 5%.

Opaques. 3% 0.2mm microphenocrysts of magnetite.

Groundmass approx 70–72% of rock. Plagioclase microphenocrysts, 0.2mm and less, about 30 %, euhedral and swallowtailed laths, with volcanic glass and magnetite. Glass is brownish, still isotropic in patches, but has some rexllised patches to murky mosaic quartz, about 15%, and maybe trace to 5% anhedral k-spar? and devitrification structures. Common patchy secondary calcite. Opaques and altered chloritised groundmass mafics, about 1–2%opaques, 8% chloritised mafics. Microphenocrysts have some degree of pilotaxitic texture, with intergranular opaques and green speckly pyriboles. Groundmass plagioclase is : RI above glue, probably not albite. Twins difficult to discern, some ML gives: 12, 12, 21, probably low end andesine or oligoclase.

Chemically, the rock is an andesite, close to the tas boundary with dacite. Microscopy supports this, but it would be easier to confirm if the pyroxenes were not altered.

Field Number		Formation:					
WI1 *		Basalt Intrusive cutting Ibáñez					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
271250	4869255		6	5	50	0	61
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
20				10			
Other components:		Others:	Total:				
Calcite/sericite		9	100				
Final Rockname							
Basaltic Dike.							

Microscopic textures (WI1): Altered basaltic rock, porphryitic with phenocrysts of plagioclase and altered pyroxene in a groundmass of plagioclase microphenocrysts with intergranular opaques and chloritised mafics. Common secondary sericitic and calcite alteration and replacment of feldspars, chlorite replacement of pyroxenes.

Plagioclase phenocrysts are sparse, 2–5%, 1–3mm subhedral and euhedral crystals, calcite replaced or sericitised, especially in cores. Groundmass plagioclase is about 45%, pilotaxitic subhedral laths, also with similar sericitic alteration or calcite replacment common. Some zoning, often destroyed by sericite excepting outer zones. Some sieve textured crystals occur, with wide sieved zones around coherent cores and rims. ML on groundmass remnant twins gives: 25, 17, 29, 32, 30, 10, 15, about An 50%, while Albite-Carlesbad gives 8, 30, about An45%, So Andesine to Labradorite.

Mafics are now chloritised, but from occasional blocky square or octagonal/rectagonal psuedomorph with remnant 'islands' were clinopyroxene, probably augite. Probably about 15–20%, up to 2mm max

Opaques are blocky, or elongate microphenocrysts of magnetite, in intergranular texture with chloritised mafics, interstitial to feldspars. 10%.

Also anhedral interstitial quartz, 0.1–0.2mm, about 5-6 %, and some anhedral feldspar, RI well below groundmass plagioclase, so trace to 5% interstitial k-spar estimated.

Field Number		Formation:					
F20 *		Basaltic Trachy-andesite Intrusive cutting Ibáñez					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
288223	4873265		3	10	60	0	73
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
			20	7			
Other components:		Others:	Total:				
			100				
Final Rockname							
Weathered basaltic trachy-andesite or basaltic andesite.							

Microscopic textures (F20): Coarsely pilotaxitic rock with network of euhedral/subhedral pilotaxitic feldspar laths with intersertal chloritised mafics and blocky intergranular opaques.

Feldspar laths are up to 1.5mm, but most 0.1–0.4mm, with well developted pilotaxtic texture, and pervasive alteration of cores to calcite. Some remnant albite twinning with low extinction angles (less than 10 degrees.) RI either just above or below epoxy, so sodic plagioclase.

Mafics are altered to green-semi opaque chlorite and clays, up to 0.5mm, about 20%. Occasional blocky octagonal section indicates that primary mineral was pyroxene.

Opaques are goethite and leucoxene, after magnetite, 5-7%.

Secondary cherty material present as interstitial material between feldspars and altered mafics, 2-3% quartz and 8-10% low RI k-spar. Too altered for QAPF, but about 60 % altered sodic plagioclase.

Field Number		Formation:					
F21 *		Basaltic Trachy-andesite Intrusive cutting Ibáñez					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
286680	4869000		1	5	60	0	66
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
			19	15			
Other components:		Others:	Total:				
			100				
Final Rockname							
Altered Basaltic trachy andesitic dike.							

Microscopic textures (F21): Fine grained pilotaxitic to framework-intergranular textured rock with altered plagioclase feldspar, chloritised mafics and opaques. Chlorite and calcite occur as void/fracture filling material.

Plagioclase is subhedral to euhedral crystals, often glomeroporphyritic in radial clusters, partly sericitised, with occasional skeletal or swallowtail textures. About 55–60%, up to 0.5mm. ML readings mainly below 20, RI fast welll below epoxy and slow just below, so Albite or albitised. Some low RI subhedral microphenocrysts in g/mass have RI below g/mass albite, so trace-k-spar, maybe 5%.

Mafics and much of interstitial spaces to plagioclase is replaced and filled by green chlorite and murky yellow green chloritic material (about 20%). Pyroxene pseudomorphs are present as blocky patches of darker green chlorite.

Opaques are blocky magnetite, about 15%.

Trace to 1% anhedral quartz.

Chemistry is mugearitic trachy-andesite, but I doubt this due to alteration in thin section, possibly with increase in sodium.

Field Number		Formation:					
WI24 *		Basaltic Trachy-andesite Intrusive cutting Ibáñez					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
270370	4863390		1	5	65	0	71
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
		4	15	10			
Other components:		Others:	Total:				
			100				
Final Rockname							
Andesitic sill.							

Microscopic textures (WI24): Porphyritic rock with poorly pilotaxitic or framework altered/albitised plagioclase phenocrysts in intergranular textured feldspar/chlorite/hematite, probably altered from an intergranular textured basic lava/minor intrusive. Chlorite and hematite are common as specks, clusters and aggregates between feldspars, and may represent alteration of an original mafic mineral. Trace pleochroic brown amphibole occurs.

Sodic Plagioclase is about 60-65%, 0.2-3mm, mainly groundmass laths, with 20% as larger phenocrysts in a matrix of feldspars/chlorite/hematite. Crystals are altered and sericitised, and cores are often replaced by chlorite or sericite, and fractures filled with opaques. ML: 6.5, 14, 7, 5, 10, 6, 12, so looks like albite, RI fast/slow both less than medium, so probably is albite. Groundmass feldspars also quite altered, RI fast strongly below medium, slow just below, so albite.

K-spar difficult to spot due to alteration of groundmass, maybe trace to 5%.

Other minerals: Hematite, after Magnetite, 15%, and chlorite 10-15%, as fine granular or fibrous material, replacing mafic minerals, with some remnant murky brown clinopyroxene present as euhedral and subhedral crystals intergranular to plagioclase.

Trace to 1% anhedral quartz in groundmass, also some apatite, epidote, amphibole.

Andesitoid or Basaltic Andesitoid, possibly with slightly albitised feldspar.

Chemistry gives Basaltic Trachy Andesite.

Field Number WI31		Formation: Minor Intrusive cutting Ibáñez					
Utm East 271139	Utm North 4858690		Q: 10	A: 5	P: 65	F:	Subtotal: 80
Cpx:	Opx:	Amph:	Chlorite: 15	Opaques: 5	Muscovite:	Biotite:	Olivine:
Other components:		Others:	Total: 100				
Final Rockname QAPF gives Q12.5,A31,P56 — Quartz trachyte to Quartz trachy-andesite.							

Microscopic textures (WI31):

Porphyritic rock with tabular, euhdral/subhedral phenocrysts of zoned feldspar, altered green tabular to blocky mafic phenocrysts, in a matted groundmass of feldspars, opaques and some mozaic quartz.

Quartz: 5–10%, in groundmass and as void filling.

Phenocryst Feldspars are up to 2mm, euhedral or subhedral slightly zoned or usually unzoned crystals, sericitised, sometimes cores replaced by sericite or green chlorite. Sometimes occurs in granular, glomeroporphyritic masses with altered mafic, presumably pyroxene. These may be xenolithic or restite fragments of refractory source material, and they appear to have a reaction rim against the surrounding groundmass. Feldspar composition. RI large phenocrysts, fast and slow well below medium, so likely Albite. Oap perpendicular 010, 2Vx about 60–80 ish — Albite. 40%, up to 3mm Albite, but bulk is groundmass material.

Groundmass feldspars, RI fast and slow also below medium, strongly, but have albite twinss, so also albite, 25% but maybe some interstitial k-spar maybe up to 5%. Some larger crystals have rim of Anorthoclase.

Mafic phenocrysts are colourless, moderate relief, stubby rectangular prismatic sections, 2v moderate, 1st red to blue, inclined extinction. Sometimes glomeroporphyritic with plagioclase, always altered to green minerals, sometimes chlorite, but sometimes something else with optical continuity with original mineral, perhaps uralite. Mineral probably originally augite/diopside clinopyroxene.

Chlorite Common, 15% as alteration of mafics and Plagioclase.

Groundmass is feldspar laths in pilotaxitic texture, with intergranular mafics, 3–5 % magnetite, green alteration product, maybe green amphibole after pyroxene.

Field Number PI87B	Formation: Minor Intrusive cutting Ibáñez					
Utm East 276250	Utm North 4873120	Q:	A:	P:	F:	Subtotal: 0
Final Rockname Hornblende hornfels (andesitic sill.)						

Microscopic textures (PI87B):

Aphanitic rock with pilotaxitic groundmass feldspars, intergranular opaques and chlorite, plus other green mica? Some porphyroblasts of euhedral but skeletal pyrite (Visible as euhedral cubes in hand specimen). Veins and relic vesicles have calcite/platy chlorite fill. Sparse epidote occurs throughout groundmass, together with some remnant green hornblende.

Feldspars are altered, euhedral laths, 0.1–0.3mm with simple ?carlsbad twinning, but appear to have altered calcic cores, so probably once plagioclase. Relatively unaltered crystals at edge of slide have Fast and Slow below epoxy medium, so Albite or Albitised.

Interspersed with these altered feldspars are patches of calcite, bright green chlorite, murky clay and occasional large porphyroblasts of secondary pyrite. Small grains of green pleochroic fibrous ?uralitic amphibole appear, probably altered from primary pyroxene or amphibole. Small, blocky, partly altered magnetite is the ubiqnitons opaque, but some of this may have been reduced to pyrite. Chlorite is negative, length slow, quite dark green, so probably something like Brunsvigite. Probably altering pyroxene from the blocky octagonal shape of some occasional large pseudomorphs.

Field Number WI15		Formation: Minor Intrusive cutting Ibáñez					
Utm East 274728	Utm North 4864366		Q: 9	A: 5	P: 65	F:	Subtotal: 79
Cpx:	Opx:	Amph: 10	Chlorite: 9	Opaques: 2	Muscovite:	Biotite:	Olivine:
Other components:		Others:	Total: 100				
Final Rockname Porphyritic hornblende quartz microdiorite.							

Microscopic textures (WI15):

Porphyritic medium grained rock, with partially altered green/brown hornblendes, large euhedral and subhedral plagioclase, some opaques, in a granular/felsitic groundmass of quartz/feldspar.

Hornblendes are pleochroic dark to light green or green to brown, altered to a mix of ?uralite/tremolite, calcite, traces of chlorite. There is also a reaction rim of opaques around the hornblendes.

Plagiocase is euhedral-subhedral, glomeroporphyritic, carlsbad-albite twinned, often partly sericitised and zoned. ML test gives:23, 30, 29.5, 31.5, 11, 27, 29 — An%46, Andesine. Carlsbad-albite test gives: 31.5/11.75, An%46, Andesine.

Perhaps also some small crystals of k-spar in groundmass. (2v small to moderate, OAP parallel 010).

Groundmass dominated by granular texture, with tablets of plagioclase, maybe some k-spar, with interstitial quartz, and some chloritised and uralitised hornblendes. Proportions, Plagioclase phenocrysts, 35%, Hornblende, 10%, groundmass remainder, 8–9%quartz, 3–5% k-spar, 30% plagioclase, 1–2% opaques, 9–10% other chloritised mafics.

Field Number		Formation:					
WI116		Minor Intrusive cutting Ibáñez					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
276425	4856430		0	5	65	0	70
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
10				3			1
Other components:		Others:	Total:				
Glass		16	100				
Final Rockname							
Basaltic andesitic dike.							

Microscopic textures (WI116):

Porphyritic rock with plagioclase and pyroxene in pilotaxitic/intergranular textured matrix. Not a similar rock to WI39 at all, presume small intrusive body, or dike big enough that I did not notice its margins among the scrub.

Plagioclase is euhedral, sometimes with sieve textures, oscillatory zoning and sometimes glomeroporphyritic with pyroxene. Some alteration to clay, sericite and replacement by calcite. ML core readings: 24, 20, 13, 15.5, 15, 12, 22. An 35, C-A gives: 22, 12 — An 35–37. Andesine. Possibly some trace of anorthoclase as rims on some crystals through which albite twins do not continue. 35%.

K-spar — Trace to 5%, possible anorthoclase rims visible on some plagioclase.

Clino-Pyroxene is sometimes oxidised, but is pale greenish with moderately high (2nd order) interference colours. 2vz moderate, +ve. Augite 10%.

Some olivine hiding among the big clusters of pyroxene & plagioclase (1%), which look like restite or xenolith material.

Groundmass is pilotaxitic textured feldspar laths with intergranular opaques, blocky magnetite, altered brown pyriboles and glassy material, with occasional microphenocryst of c-pyroxene. RI indicates groundmass felspars are probably calcic oligoclase. Oligoclase plagioclase, 30%, glassy stuff and pyriboles, 15–16%, opaques, 3%.

Field Number	Formation:					
WI94	Minor Intrusive cutting Ibáñez					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
272810	4864500					0
Final Rockname						
Albite-Epidote hornfels. (Andesitic-dacitic sill.)						

Microscopic textures (WI94):

Altered porphyritic rock, with intergrauular textured groundmass and altered large mafic phenocrysts. Mafic phenocrysts appear to be green hornblende, altering to Chlorite and opaques. Trace brown and green hornblende in groundmass. (Maybe secondary, green possibly actinolitic.) Common secondary anhedral to subhedral yellow-green Epidote porphyroblasts, grown in and around groundmass material.

Groundmass is of feldspars altered by Calcite/sericite, but zoning and albite twins visible. ML gives:10.5, 11.5, 9.75, 11, 12.5, 13, Oligoclase or Albite, RI indicates Albite. Many larger feldspar phenocrysts have fine epidote and calcite crystallised within them, plus sericite, while remaining feldspar is albitised — Saussauritisation. Groundmass feldspar occurs with disseminated anhedral quartz, secondary chlorite, epidote, calcite, etc, and is also sericitised.

Quartz in groundmass appears slightly recrystallised.

Hornblende phenocrysts are pleochroic green and brown, has chaotic reaction rims with opaques and chlorite. Some may be uralitised, also often chloritised.

Albite-Epidote facies hornfelsed or hydrothermally altered dacitic andesitic intrusive.

Field Number	Formation:					
WI40A	Minor Intrusive cutting Ibáñez					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
274470	4858508					0
Final Rockname						
Altered andesitic intrusive.						

Microscopic textures (WI40A):

Altered rock, with well developed pilotaxitic texture of altered feldspars, mainly groundmass, but sparse euhedral phenocrysts from 0.5mm up to 1mm. All are altered to fine grained platy sericite and calcite, but from crystal shapes (long, platy or tabular crystals and sparse remnants of carlsbad twins.) were probably anorthoclase.

Groundmass is sericitised pilotaxitic feldspar microphenocrysts, with some development of mosaic quartz, but common alteration is patchy calcite and sericite, with large irregular patches of chlorite. Mafics are altered to chlorite, while leucoxene replaces original opaque microphenocrysts. Trace apatite is unaltered.

Rock was probably an andesite.

Field Number	Formation:					
WI40C	Minor Intrusive cutting Ibáñez					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
274470	4858508					0
Final Rockname						
Altered andesitic dike.						

Microscopic textures (WI40C):

Strongly altered trachytic textured volcanic rock. Pilotaxitic groundmass has remnant feldspar microlites, recrystallised to ghostly poikilomosaic of quartz about remnant feldspars, and some feldspar pseudomorphed by calcite, and intergranular texture of magnetite, green fine grained pyriboles, and chlorite. Streaks observed in hand specimen are en-echelon extension fractures filled with quartz-mosaics, and surrounded by wide alteration halos in the trachytic groundmass. Calcite & sericite pseudomorphs replace glomeroporphyritic ?albite feldspar clusters up to 3mm across. Both groundmass recrystallised quartz have LPO and feldspars have SPO parallel to trachytic texture and en-echelon fractures. Quartz in the fractures has no LPO. Slightly sheared and altered andesitic dike.

Field Number	Formation:					
WI65A	Minor Intrusive cutting Ibáñez					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
271400	4869230					0
Final Rockname						
Altered basaltic andesitic/andesitic sill.						

Microscopic textures (WI65A):

Even grained feldspar rich volcanic rock, moderately well developed pilotaxitic orientation of feldspar laths, with round vesicles filled with radial clusters of chlorite or calcite patches. Opaques, cherty fine material and chlorite patches are intergranular to feldspars.

Felspars are quite sericitised, but dominated by plagioclase, probably Oligoclase-Andesine. ML not possible, RI suggests Albite or Albitised.

Altered basaltic andesitic/andesitic sill.

Field Number	Formation:					
WI83B	Minor Intrusive cutting Ibáñez					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
272280	4863180					0
Final Rockname						
Albite epidote hornfels. (Andesitic dike.)						

Microscopic textures (WI83B):

Porphyritic volcanic rock, with euhedral, glomeroporphyritic phenocrysts of plagioclase and chloritised pseudomorphs of a mafic phase, in a groundmass of pilotaxitic/framework altered feldspar laths with intergranular opaque magnetite and patches of secondary chlorite, clays. Trace apatite, as well as secondary quartz and epidote as alteration product.

Feldspars, 0.2–3mm, 15–20% are extensively sericitised, some with flakes of muscovite, often with calcite. Large phenocrysts are Plagioclase, Albite-Carlsbad twinning gives: 4.5, 21.5 ⟶ An%32, Andesine. Phenocrysts are oscillatory zoned, euhedral-subhedral, glomeroporphyritic. Sericitisation is fairly pervasive, but concentrated towards the core in many crystals.

Altered Mafics, 0.2–1.5mm, 5%, presumably pyroxene from blocky, rectangular pseudomorphs in calcite and bright green chlorite, (Chlorite in pseudomorphs is mostly of the brown variety in cpl, +ve, length fast.)

Groundmass: Pilotaxitic/intergranular feldspars of 0.2mm and smaller, with intergranular opaques and small altered mafics (mostly chlorite), recrystallised in some places to murky quartz/feldspar felsitic mosaic. Vesicles are filled with bright purple-lavender cpl chlorite, together with quartz, calcite, maybe adularia, some epidote. Trace Apatite.

Altered Andesitic dike.

Field Number	Formation:					
WI92	Minor Intrusive cutting Ibáñez					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
272450	4865020					0
Final Rockname						
Weathered and altered andesitic dike.						

Microscopic textures (WI92):

Strongly altered porphyritic rock, with pseudomorphs of mafic phenocrysts in calcite/chlorite and opaque, and sericitised and clayey feldspars, in a fine grained matrix of altered pilotaxitic to randomly arranged feldspar and blocky opaques, with occasional quartz.

Dominant phenocryst is altered green mafic pseudomorphs. Crystals appear to have been amphiboles, from their long prismatic sections and blocky, six sided cross sections. About 10–15%, up to 2 or 3mm long. Alteration is to green pleochroic chlorite and opaqne magnetite, apparently part of a reaction rim, and calcite, leucoxene and chlorite in the cores, with occasional apatite. Possibly some with uralite alteration also.

Remainder of rock is brownish altered feldspar phenocrysts and groundmass of altered feldspar, opaques, calcite, chlorite and minor secondary quartz. Feldspars used to be sodic plagioclase, but are now altered to sericite, calcite and clay. Fine grained chlorite is disseminated throughout the groundmass, as is patches of calcite, and blocky finegrained opaques in intergranular texture with the altered feldspars.

Field Number	Formation:					
WI122	Minor Intrusive cutting Ibáñez					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
273005	4864236					0
Final Rockname						
Altered andesitic to dacitic sill.						

Microscopic textures (WI122):

Porphyritic rock with altered brown to green brown amphibole phenocrysts in a groundmass of poorly pilotaxitic feldspar, replaced by sericite, calcite and saussurite, with intergranular altered opaques and secondary chlorite and epidote.

Amphibole is green to brown pleochroic hornblende, 0.5–1mm, about 5–10%, with reaction rim of carbonates and opaques.

Large feldspar phenocrysts are rare, and are saussuritised, to albite, epidote, sericite and calcite. Groundmass feldspar is also similarly altered, with patchy calcite, sericite, and fine grained epidote.

Cavities are filled with radial chlorite platy aggregates and/or calcite.

Groundmass also has trace quartz, difficult to tell whether primary or secondary.

Field Number	Formation:					
WI100	Minor Intrusive cutting Ibáñez					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
273320	4862770					0
Final Rockname						
Altered microdiorite or microgranodiorite.						

Microscopic textures (WI100):

Porphyritic microgranitoid, with subhedral crystals of altered plagioclase and chlorite pseudomorphs of mafic minerals in an altered matrix of plagioclase, quartz and opaque minerals. Alteration includes epidote, chlorite, calcite, etc. This rock is more altered than the WI98 sample and also somewhat more porphyritic, with greater numbers of mafic and plagioclase phenocrysts. Otherwise texturally similar.

Large plagioclase phenocrysts are up to 5mm, most 2–3mm, about 5% of the rock. Crystals are euhedral to subhedral, some times zoned. Alteration consists of pervasive fine cracking with growth of sericitic material, and growth of sprays or clusters of epidote within plagioclase, possibly with related albitisation. RI of large phenocrysts has fast and slow directions fairly strongly below medium, which indicates Albite. Alteration matches Saussuritisation.

Groundmass plagioclase is more altered than the larger phenocrysts, and is murky, cracked, seamed with sericite or calcite and sometimes intimately associated with clusters of murky anhedral epidote.

Quartz occurs as fine anhedral grains in the groundmass, interstitial to the altered plagioclase. Some is probably secondary, and some areas have been recrystallised to mosaic quartz.

Mafics are blocky or elongate pseudomorphs of green chlorite with purple interference colour, often mixed with subhedral or euhedral clusters of epidote. Shape of some pseudomorphs indicates they may have been an amphibole, probably the green hornblende found in WI98

Opaques include blocky square pyrite, and altered, oxidised magnetite and hematite.

Field Number	Formation:					
PI68	Minor Intrusive cutting Ibáñez					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
272540	4873560					0
Final Rockname						
Microgranodiorite dike.						

Microscopic textures (PI68):

Sparse rounded bipyramidal quartz, sericitised rounded zoned plagioclase and chlorite altered Hornblende phenocrysts in felsitic/intergranular groundmass of felspar microphenocrysts, magnetite and recrystallised to quartz mozaic. Common calcite as alteration of feldspars in phenocrysts and groundmass.

Large plagioclase is sodic Oligoclase by RI. Some simple oscillatory zoned plagioclase altered by separate zones to calcite, or sericite, and some unaltered zones. Groundmass plagioclase is also zoned, perhaps rimmed with k-spar. RI indicates albite.

Long patches of pleochroic green chlorite ± calcite, quartz, and trace epidote appear to be pseudomorphs of Hornblende. Trace tridymite (biax+, pseudo hex plates, fast along) and trace cristobalite, low birefring, uniax.-ve. (maybe apatite.) Some monazite or zircon. Hybabyssal Tonalitic/grandioritic dike.

Field Number	Formation:					
GA17	Minor Intrusive cutting Ibáñez					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
286998	4866155					0
Final Rockname						
Weathered and sericitised andesitic sill.						

Microscopic textures (GA17):

Rock is feldpar rich, porphyritic textured with large plagioclase phenocrysts in a feldspar groundmass, intergranular textured, with some magnetite and secondary chlorite, calcite, and perhaps trace primary quartz, although some euhedral quartz may be secondary cavity infill material.

Quartz occurs in trace amounts as small, anhedral crystals in the groundmass.

Feldspars appear to be sodic oligoclase or albite, but difficult to tell with alteration. All feldspars are sericitised, groundmass feldspars have vague trachytic orientation, but stubby crystal shape makes this a vague texture. ML on remnant albite twins in groundmass plagioclase: 14.5, 16, 17.5, 9.5, 14, 12, 9. An% close to 0 or 20–25ish, so Albite or Calcic Oligoclase. RI is fast and slow below epoxy medium, so probably Albite.

Mafic minerals now altered to calcite/chlorite/opaques, but from pseudomorphs, appear to have been an amphibole.

Trace Apatite in cavities, low relief, birefringence. But has anomalous biaxial negative int(ernal?) figure in some cases.

Calcite common in groundmass, as alteration/replacement mineral.

Probably an andesite. Too altered for chemistry.

Field Number		Formation:					
F8C *		Trachy-andesite Intrusive cutting Ibáñez					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
287390	4869125		5	15	55	0	75
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
			5	8			
Other components:		Others:	Total:				
Devitrifying glass		12	100				
Final Rockname							
Hydrothermally altered andesitic Lava or sill (Chemistry is Trachy Andesite.)							

Microscopic textures (F8C):

Porphyritic vesicular rock, with phenocryst phase of plagioclase in a fine grained pilotaxitic groundmass.

Feldspar phenocrysts are euhedral-subhedral sodic plagioclase, murky and altered with sieve texture, some synneusis twins, albite twins, sometimes glomeroporphyritic, up to 4mm, about 20%. Some crystals appear poikilitic around opaque, possibly Ilmenite. ML max reading on albite twins is 18.7, giving An% 0 or 25ish. RI is either fast and slow below medium or fast below and slow above, so range from sodic Oligoclase to Albite.

Original mafic phase are blocky, elongate phenocrysts, up to 1mm, euhedral rectangular pseudomorphs of fibrous chlorite. Probably after pyroxene. 5%.

Groundmass is 75% of rock, with fine grained poorly pilotaxitic feldspar laths with occasional albite twinned crystals, with granular opaques and altered brown mafics set in brown glass, which is partially recrystallised anhedral mosaic material. Gronndmass feldspar is below .05mm, fine, no discernable twins, has RI well below epoxy, so likely to be albite. Estimate about 5–8% paques and altered mafics, 35% fine albite laths, maybe 10–15% k-spar and 5% quartz as mosaic groundmass material. However, much groundmass feldspar is recrystallised into mosaic material, faintly visible under CPL as coherent extinction patches.

Vesicles are lined with fine cherty quartz and filled with green platy chlorite, with anomalous brown interference colours.

Secondary void filling is of calcite, cherty quartz, bright green fibrous chlorite and occasional sericitic mica.

Field Number		Formation:					
L17A *		Trachy-andesite Intrusive cutting Ibáñez					
Utm East	Utm North		Q:	A:	P:	F:	Snbtotal:
284860	4859830		0	2	80	0	82
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
5			5	8			
Other components:		Others:	Total:				
			100				
Final Rockname							
Altered Andesitic sill.							

Microscopic textures (L17A):

Porphyritic rock with altered Fe-oxide rimmed hornblende/oxyhornblendes and subhedral pale ?olivine/pxne in a felsitic/intergranular groundmass of feldspar and opaques. Patches of calcite occur as alteration of groundmass and phenocrysts.

Hornblendes are mid to dark green pleochroic, rimmed with opaques, and often altered entirely to pseudomorphs of opaques at rim, core of calcite/chlorite. Perhaps some Uralite about. Up to 2mm, 2–5%.

Pale Mafic. Presumably pyroxene, as crystal shape and interference colours not quite right for Olivine. 2v low, positive. From colourless, white appearance in PPL, I think Diopside. 2mm max, 2–5%. No good cleavage sections seen, but extinctionn angle and octagonal end sections match. Glomeroporphyritic and altered to opaques, chlorite and calcite in some sections.

Groundmass: About 90% of rock, 80% Tabular euhedral-subhedral feldspars in poor pilotaxitic texture, with about 5–8% intergranular opaques and 4-5% green chlorite from altered mafics. Feldspars seem to be Albite, ML about 10 %an, RI also suggests albite. Quite strongly altered/sericitised. K-spar may be present as anhedral low RI colourless material interstitial to sodic plagioclase, trace to 2%.

Probably Andesitic. Chemistry gives Trachy-Andesite, bnt I think this is due to alteration from the banding effect observed in ontcrop increasing proportions of Alkali elements, particularly sodinm.

Field Number		Formation:					
F2C *		Trachy-andesite Intrusive cutting Ibáñez					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
288123	4865027		1	5	70	0	76
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
			10	10			
Other components:		Others:	Total:				
Calcite voidfill		4	100				
Final Rockname							
Altered andesitic/trachyandesitic sill.							

Microscopic textures (F2C):

Medinm grained trachytic textured rock with coarse 0.5–2mm euhedral 60% sodic plagioclase and 10-20% ?K feldspar, 1% quartz.

Feldspar phenocrysts are pilotaxitic about intergranular opaques and chloritised mafics. Some patches of calcite alteration. Plagioclase is murky and sericitised, some of which has coarsened up to muscovite plates. Plagioclase ML gives Ambiguous AN 5 or 20%, RI Fast and slow are below epoxy, so Albite or Albitised. About 70% of rock.

Some plagioclase phenocrysts have low RI rims and also some low RI material occurs as anhedral interstitial crystals. Probably trace anorthoclase, trace to 5% max.

Quartz is trace to 1%, as anhedral interstitial material between sodic plagioclase phenocrysts., secondary mineral in vesicles, cavities, and perhaps as cherty intergrowths in cavities.

Mafics are green and altered anhedral material interstitial to plagioclase. Now altered to bright green pleochroic chlorite or fibrous uralite. Difficult to tell if pyroxene or hornblende in original state as crystals are anhedral. About 10%.

Opaques are blocky euhedral to subhedral magnetite, about 8–10%.

Hypabyssal Andesite/Trachyandesite. (Chemistry gives TAS trachyandesite.)

Field Nnmber	Formation:					
F5A *	Vent breccia cutting Ibáñez					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
287814	4866122					0
Final Rockname						
Hydrothermally altered and weathered Andesitic Vent Breccia.						

Microscopic textures (F5A):

Andesitoid breccia of rounded juvenile fragments, along with country rock fragments of rhyolitoid material and quartz crystals, matrix supported in a finely comminuted matrix of similar material to the andesitoid fragments, with less crystals and no orientated phenocrysts.

Andesitoid fragments are rounded, pilotaxitic, with much alteration and replacement by clay and calcite. Round vesicles are filled with calcite and light green chlorite. Feldspars are altered, clayey or calcite patch replacement, laths are pilotaxitic, sometimes albite or carlsbad twinned, RI fast and slow below epoxy, so probably Albite. Groundmass of fragments is similar to groundmass of matrix, but with more chlorite and vesicles, as well as occurrence of patches of pilotaxitic microphenocrysts and intergranular altered mafics.

Groundmass is fine grained chlorite and felsitic material, together with stray broken, fractnred crystals of feldspar, ocasional quartz, fine rock fragments. Quartz appears to be rounded and fractured bipyramids derived from surrounding rhyolitic tuffs through which this ?vent breccia punches. Rhyolitic country rock fragments also occur.

Field Number	Formation:					
CF13A	Vent Breccia cutting Ibáñez and Divisadero					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
273179	4877563					0
Final Rockname						
Polymictic vent breccia with primary dacitic juvenile material and pulverised and brecciated country rock fragments.						

Microscopic textures (CF13A):

Polymictic matrix supported breccia, with clasts of altered ?Ibáñez country rock and ?juvenile volcanic material in a matrix of felsitic material, broken crystals and secondary calcite and sericitic alteration.

Juvenile igneous clasts are rounded, porphyritic, with altered and sericitised sodic plagioclase, euhedral hornblende (chloritised) and some quartz in a groundmass of coarse felsitic to granular quartz/feldspar mosaic material. Looks like hypabyssal dacitic to rhyolitic material.

Rock fragments are angular, altered tuffs, sediments, intermediate volcanics with pilotaxitic feldspars, all either oxidised, devitrified and often sericitised where feldspars were present.

Crystal fragments include large, 0.2–2mm fragmentary or fractured bipyramidal quartz, presumably from country rock fragmentation, as this does not occur commonly in the rounded juvenile igneous clasts. Also sericitised sodic plagioclase, similar size range, and often replaced by calcite as well as sericite.

Matrix is fine felsitic textured material and many crystal fragments, patchy sericite, calcite cement and void fill and fine grained rock fragments of altered ?Ibáñez tuffs and sediments.

Field Number		Formation:					
F39B *		Basaltic Trachy-andesite Intrusive cutting Ibáñez and Coyhaique Group					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
284325	4869300		4	2	60	0	66
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
			15	10			
Other components:		Others:	Total:				
Calcite/quartz voidfill		9	100				
Final Rockname							
Qapf gives just inside Trachy-Andesite field, Quartz trachy-andesite, while chemistry gives Basaltic trachy andesite,but this may be due to alteration.							

Microscopic textures (F39B): Porphyritic rock with phenocryst phases of altered plagioclase, mafic minerals replaced by chlorite, and blocky magnetite, in a groundmass of plagioclase and altered mafics plus opaques in intergranular texture.

Plagioclase phenocrysts are euhedral to subhedral, sometimes glomeroporphyritic, murky and altered. Up to 3–4mm, maybe 25%. Often porous or sieve textured with opaques or chlorite/calcite alteration filling cavities. Some zoning, mainly a simple less altered outer rim. Poor ML readings: 10 down to 3, while RI of high birefringence plag has fast well below epoxy and slow moderately below, so Albite or Albitised.

Groundmass is about 35% microphenocrysts of sodic plagioclase, with 10% intergrauular blocky magnetite, and trace interstitial k-spar (1–2%), 4–5 anhedral, irregular quartz, about, with 15% chlorite after mafic phase, and secondary chlorite, calcite and quartz as vesicle filling.

Mafic phases both in phenocrysts and groundmass are blocky square or elongate pseudomorphs of fibrous or radial low RI platy pleochroic green length slow minerals, probably Antigorite/serpentine, while some with anomalous blue interference colours will be chlorite. Shape of pseudomorphs suggests they were pyroxene.

Field Number		Formation:					
F29 *		Trachy-andesite Intrusive cutting Coyhaique Group					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
286050	4870730		0	20	60	0	80
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
2		8		10			
Other components:		Others:	Total:				
			100				
Final Rockname							
Trachy-andesitic or altered andesitic vent breccia.							

Microscopic textures (F29):

Brecciated rock with common crystal fragments of sodic plagioclase, green hornblende, pilotaxitic basaltic/andesitic rock fragments, dioritic rock fragments and a matrix of fine grained comminuted crystal fragments. A lot of secondary alteration, and hematite staining, cementation, etc.

Feldspar crystal fragments are about 80% of the rock, mostly subhedral and sometimes polycrystalline granitic fragments of sodic plagioclase, with patchy recrystallisation and replacement to k-spar, discernable by RI changes within crystals. Rock has had significant recrystallisation, with crystal fragments showing mosaic patchy recrystallisation cutting across original crystal and polycrystalline fragment boundaries. Twinning is rare, and original feldspar probably perthitic from pervasive intergrowth of k-spar and plagioclase, now partially recrystallised, estimate about 60% albite-oligoclase and 20% orthoclase. Rare albite-carlsbad twin gives 10,22, about An 35% or less than An10%, while RI on same crystal has both fast and slow below epoxy, so probably albite rather than oligoclase.

Mafics are occasional crystals of pale green pyroxene and bright green pleochroic hornblende, up to 0.5mm. About 5–8% amphibole, trace to 1–2% pyroxene. No discernable quartz, and interstitial to clasts is common secondary hematite, about 10%.

Trachy-andesitic vent breccia.

Field Number		Formation:					
S3 *		Andesite Intrusive cutting Divisadero					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
282264	4877008		15	5	55	0	75
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
2	8			10			
Other components:		Others:	Total:				
remnant glass		5	100				
Final Rockname							
Hypabyssal to subvolcanic or maybe extrusive basalt to basaltic andesitoid, from occurrence of two pyroxenes. Needs more feldspar determinations in gmass.							

Microscopic textures (S3): Porphyritic rock with large (up to 4mm) phenocrysts of plagioclase and pyroxene in a fine grained groundmass of opaques, pilotaxitic feldspar microphenocrysts and intersertal glass and groundmass felspar.

Plagioclase (30%) is euhedral to subhedral, often glomeroporphyritic and sieve textured. Some oscillatory zoning. C-A on larger phenocrysts: 12.5, 27, About an 45, and 11, 32.5, about An 55%. Section Ta also gives about An 45%. So larger phenocryst plagioclase varies between

Sodic Labradorite and Calcic Andesine. Larger population varies between simple, slightly zoned euhedral crystals, then large, glomeroporphyritic subhedral to granular clusters with oscillatory zoning, then a third population of large crystals with distinctly dense and rounded sieve textured rim followed by slightly more calcic overgrowth.

Groundmass (50-60% of rock) is of fine granular opaques and partially recrystallised glass with some plagioclase as small euhedral laths, sometimes glomeroporphyritic, slight trachytic texture, some swallowtail texture. Intersertal glass has some recrystallisation to patchy mosaic quartz/feldspar, but very indistinct, with intergranular fine opaques and pyroxenes between plagioclase microphenocrysts. Groundmass feldspars are 0.1–0.2mm, C-albite twin gives: 6, 30, about An 50–55%, Labradorite. Overall, groundmass is about 25% plagioclase, 20% mosaic material recrystallised from glass, 10% fine mafics and opaque minerals. Estimate about 10-15% of mosaic material is quartz, 5% k-spar.

Dominant mafic (10%) is a mixed population of slightly greenish to brownish pyroxenes, one with, moderate birefringence, straight small extinction angle, biaxial negative, moderate 2v, probably Orthopyroxene, and the other is of higher birefringence, moderate extinction angle, biaxial positive, small to moderate 2v, probably subcalcic augite to augite. Some complexely laminated crystals have both augite and orthopyroxene within them. Uralitic alteration occurs. 2%cpx, 8% opx, about. Many of the pyroxenes, but mostly orthopyroxene? Appear to be associated with fine grained to medium grained granular xenoliths of refractory material, mostly plagioclase and pyroxene.

Field Number		Formation:					
F33 *		Andesite Intrusive cutting Divisadero					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:	
284510	4872370	15	5	60	0	80	
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
15		1		4			
Other components:		Others:	Total:				
			100				
Final Rockname							
Petrographically andesite, chemically also andesite. Presence of hornblende in groundmass and labradorite to Andesine plagioclase range confirms this.							

Microscopic textures (F33): Moderately altered porphyritic andesitic rock. Porphyritic with phenocrysts of plagioclase, altered pyroxene, magnetite, in an intergranular groundmass of plagioclase, opaques, fine grained pyroxene. Alteration is common, with secondary calcite as vein and void filling, also as core alteration of some plagioclase. Sericite is present as feldspar alteration, and pyroxenes are psendomorphs with almost complete replacement by chlorite, green/brown biotite and fibrous uralite.

Plagioclase phenocrysts are euhedral to subhedral, up to 5mm, often oscillatory zoned, about 40%. Michel levy test on unzoned crystals gives 28, 20, 24, 27, 26, 32 and 34 degrees, about An 60%, Labradorite.

Pyroxene is blocky euhedral phenocrysts, pseudomorphed by pleochroic fibrous green chlorite and fibrous pleochroic green-brown biotite? And also by fibrous uralite. Up to 3–4mm, euhedral, about 10%. Probably once augite, now completely altered to pseudomorphs by chlorite/biotite/nralite.

Groundmas is about 40% of the rock, with plagioclase as fine laths, sub .1mm, enhedral, but often with a swallowtail step. Plagioclase microphenocrysts are about 20% of the groundmass. ML is difficult, readings: 29, 24, 23, 18, 12, 21, 16, About An 45%, Andesine. Remainder of groundmass is intergranular texture with 4–5% oxidised brown opaques,some apatite, 5–6% chlorite as green matted material replacing groundmass pyroxenes and irregular anhedral interstital quartz, about 15%, maybe trace to 5% kspar. Occasional green brown hornblende (trace-1%), and common secondary calcite, chlorite, hematite as void filling material and replacement minerals.

Field Number		Formation:					
S6 *		Basaltic Andesite Intrusive cutting Divisadero					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:	
283956	4878304	10	5	65	0	80	
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
4	6			5			5
Other components:		Others:	Total:				
			100				
Final Rockname							
Basaltic Andesitoid high level intrusive or lava.							

Microscopic textures (S6): Porphyritic rock with phenocrysts of plagioclase, pyroxene and iddingsitised olivine, in a groundmass of pilotaxitic plagioclase feldspar and fine grained intergranular mafics and opaques.

Olivine is present, trace to 5%, anhedral to subhedral pseudomorphs up to 2mm, composed of bright red brown amorphous iddingsite, and in some cases greenish chlorite. Distinguishable as olivine by the occurrence of a couple of euhedral double pointed or lozenge shaped prismatic crystals. Otherwise rounded, and with reaction rims.

Plagioclase is bimodal, as 0.5 to 3mm euhedral/subhedral phenocrysts, (20%) and as fine sub 0.2mm groundmass microphenocrysts. Larger population is euhedral to subhedral, occasionally oscillatorily zoned or sieve textured, sometimes radially or irregularly glomeroporphyritic. At least one crystal is surrounded by altered olivine in a variety of "frame" texture. Core ML: 35, 7, 24.5, 39.5, 34.5, 34, 36. About An 68%, although zoned crystals have oscillatory zoning, most tend to be overall normal, with about 5–10 degrees reduction in extinction angle at the rim, so crystals appear to be zoned from An68 at cores to An50 or 45 at rim. Zoned, Labradorite cores to Calcic Andesine at rims.

Pyroxene is slightly grey-brown, mainly as granular fine material in groundmass, but also as occasional phenocrysts, Subhedral to euhedral crystals up to 2mm, and similar to S3, there are both Augite, distinguishable by high birefringence and inclined prismatic extinction, and Orthopyroxene, with low birefringence and prismatic straight extinction. Orthopyroxene tends to be glomeroporphyritic or associated with granular xenoliths of restite material. About 5–6% Opx, 3–4% cpx, with Opx being more common as larger phenocrysts.

Groundmass is about 40–45% fine grained pilotaxitic plagioclase in intergranular texture with interstitial pyroxene (see above) and magnetite (5%), with some (15%) anhedral colourless material in groundmass from both uniaxial positive figures in some patches and low Rl in others, about 10% quartz and 5% k-spar respectively. Plagioclase by ML is: 23.5, 30, 19, 26, 24, 30.5, 31, About An45%, Andesine. Also patches of greenish and brownish alteration, and perhaps some remnant glass.

Field Number		Formation:					
LH12 *		Basaltic Andesite Intrusive cutting Divisadero					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
279244	4878797		10	12	50	0	72
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
15		3		5			
Other components:		Others:	Total:				
Altered glass		5	100				
Final Rockname							
Basalt or Basaltic andesite feeder dike to Plateau basalts.							

Microscopic textures (LH12): Aphanitic rock composed of poorly pilotaxitic plagioclase microphenocrysts, with both intergranular pyroxenes and opaques, and interstitial low Rl k-spar and minor quartz, with some patches of brown glass in intersertal texture. Occasional phenocrysts of larger, up to 1mm plagioclase and pyroxene occur.

Plagioclase microphenocrysts are euhedral, about 0.1mm, sometimes with slight swallowtail texture. Feldspars are flow aligned, but not well. ML: 18.5, 23.5, 21, 20, 19.5, 30, 31.5, about An 48-50%, Andesine. Smaller phenocrysts are more sodic, occasional large phenocrysts more calcic. About 50% of rock.

Glass is intersertal to all other microphenocrysts, brown with black microlites in ppl, generally opaque in cpl, but some has devitrified to murky brown material. About 5%

Groundmass anhedral colourless material is mostly biaxial, small positive 2v, Rl also mainly well below plag, so probably k-spar with some quartz, estimate 10-12% k spar and 8-10% quartz.

Fine grained granular mafic in groundmass is pyroxene, probably mostly augite, although some low Rl crystals may be orthopyroxene. Some pyroxene is altered to bright green chlorite, but not much. Maybe some uralitisation. About 15%

Minor occurrence of bright green Hornblende in groundmass.

Dominant opaque is magnetite, small, blocky microphenocrysts, about 5%

Field Number		Formation:					
F27B *		Basaltic Trachy-andesite Intrusive cutting Divisadero					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
287660	4873900		5	15	55	0	75
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
7	2			5			1
Other components:		Others:	Total:				
Glass		10	100				
Final Rockname							
Basaltic Trachy-andesite sill.							

Microscopic textures (F27B): Porphryitic rock with phenocrysts of euhedral plagioclase and clinopyroxene in a groundmass of granular plagioclase and pyroxene microphenocrysts with some intersertal brown glass.

Large plagioclase phenocrysts are about 25% of the rock, euhedral to subhedral crystals with oscillatory nomal zoning and sieve textures, between 1-3mm. Carlsbad-albite gives 7, 39 at core and 2, 12 at rim, so about An70% down at cores to An 25% at rim, Labradorite to Oligoclase. Sieve textured plagioclase includes some glass within crystals and some crystals are poikilitic about augite phenocrysts.

Clinopyroxene phenocrysts are slightly brownish augite, subhedral crystals occasionally poikilitically enclosed by plagioclase, about 5%, 0.5–1mm. Some alteration to murky green chlorite.

Occasional large orange lozenge shaped pseudomorphs of amorphous or fibrous iddingsite or green matted material, perhaps bowlingite, with reaction rims of opaques, perhaps trace to 1% altered olivine.

Groundmass is about 74%, mainly intergranular plagioclase microphenocrysts, granular clinopyroxene and blocky magnetite, with intersertal brown glass patches and small patches of low Rl anhedral intersertal and very slighty granophyric k-spar, with fine quartz intergrowth. Groundmass plagioclase microphenocrysts are euhedral to subhedral with stepped swallowtail quench textures, albite-carlsbad twins give 4.5, 21, about An28-30%, Oligoclase. Some groundmass augite has rims or lamellae of orthopyroxene. Plag:30%, Glass: 10%, Augite 7%, Opx 2%, k-spar 15%, quartz 5%, opaques 5%.

Field Number		Formation:					
F69 *		Basaltic Trachy-andesite Intrusive cutting Divisadero					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
281570	4870550		3	16	50	0	69
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
15				10			
Other components:		Others:	Total:				
calcite/sericite		6	100				
Final Rockname							
Petrographically a quartz trachy-andesitoid or basaltic trachy-andesitoid, chemically Basaltic Trachy Andesite.							

Microscopic textures (F69): Fine grained, equigranular rock with pilotaxitic/intergranular textured plagioclase, magnetite, altered mafics, with secondary calcite, sericite, iron oxides.

Plagioclase is fine euhedral microphenocrysts, up to about 0.2mm, about 50%. ML gives 7, 6.5, 17, 24, 7.5, 23, 25.5, about An 35%. C-Albite gives: 11,22 degrees, also about AN 35%, sodic Andesine. Some swallowtail quench textures.

Oxidised opaques are about 10%, intergranular to plagioclase, mainly magnetite, often altered to hematite. Calcite and sericite occur as voidfill and alteration in groundmass, and patches of green chlorite or uralitic, calcite and red hematite pseudomorph a mafic phase, of which remnants show augite clinopyroxene interference colours, about 15%.

Anhedral colourless material intersertal to plagioclase and mafics contains some quartz, 3%, and other material is very low RI, biaxial -ve, anhedral groundmass k-spar, about 15-16%.

Field Number		Formation:					
F64A *		Basaltic Trachy-andesite Intrusive cutting Divisadero					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
281130	4868670		5	15	48	0	68
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
10				10			
Other components:		Others:	Total:				
Altered glass		12	100				
Final Rockname							
Altered Basaltic Andesite by microscope. Chemistry gives Basaltic Trachy-Andesite.							

Microscopic textures (F64A): Altered basaltic intrusive, porphyritic with altered plagioclase and pyroxene phenocrysts in an intergranular matrix of finer plagioclase, pyroxene, opaques and common green-brown partly devitrified glass with fine grained mafics, often skeletal.

Plagioclase phenocrysts (5–8%) are pervasively altered in cores to yellow-green or brown slightly pleochroic granular or platy mineral. Also common sieve textures. Carlsbad Albite on relatively unaltered crystal gives: 31,7, about AN45-50% , Calcic Andesine. Alteration product is difficult to identify, may be chlorite group, probably not epidote.

Pyroxenes are small subhedral augite, up to 2mm, but most in groundmass, also altering to uralite/chlorite.

Calcite occurs as vein mineral, also as alteration product of feldspar, and together with cherty quartz, sometimes as vesicle or void filling.

Groundmass is intergranular textured plagioclase (40%) and brown to green amorphous chlorite/uralite pseudomorphing pyroxene (8—10%) microphenocrysts, with intersertal altered greenish or brownish alteration product, sometimes fibrous and biotite like, otherwise amorphous, presumably after glass, about 12%. Also about 10% fine opaques and some chlorite as alteration product of mafic minerals. Trace to 5% anhedral interstitial quartz and anhedral low RI interstitial k-spar, more than quartz, about 15%. Microphenocrysts give C-Albite reading 12, 22, about An38%, Sodic Andesine

Field Number		Formation:					
F68 *		Basaltic Trachy-andesite Intrusive cutting Divisadero					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
282850	4869930		5	15	55	0	75
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
15			5	5			
Other components:		Others:	Total:				
			100				
Final Rockname							
Basaltoid or Basaltic Andesitoid. Chemistry gives Basaltic trachy Andesite, but dodgy due to degree of alteration revealed in thin section and high LOI.							

Microscopic textures (F68): Basaltoid rock, with plagioclase, and secondary calcite, chlorite, sericite, etc, replacing much of the original mineralogy.

Plagioclase is present as fine 0.2–0.5mm euhedral groundmass microphenocrysts, about 55% of rock, including 10% large 2-5mm zoned euhedral phenocrysts with cores showing sievetexture and serictic or calcite and clay alteration, with trace epidote. Albite-Carlsbad on groundmass plagioclase gives: 15,27, about An45% and 15, 33, up to An55%, so Calcic Andesine toSodic Labradorite. Large phenocrysts are quite altered, but section Ta gives 41, about An75%, Bytownite.

Calcite, green chlorite and clay appear to have effectively obliterated any pyroxene, although small remnants showing clinopyroxene level interference colours occur within some of the blocky or squareish chlorite/uralitic pseudomorphs. Probably about 10-15% before alteration

Groundmass is intergranular framework of andesine microphenocrysts, about 5% anhedral small quartz, and 5% opaques, 5% chlorite after ?pyroxene, and void filling calcite. Void filling of chlorite, calcite and cherty quartz occurs. Any original intersertal glass or k-spar is not discernable due to alteration products and secondary calcite, hematite, chlorite, but extrapolation from chemistry gives about 15% k-spar.

Field Number		Formation:					
F34		Minor Intrusive cutting Divisadero					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
286190	4873170		15	10	55	0	80
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
15				5			
Other components:		Others:	Total:				
			100				
Final Rockname							
Andesitic or basaltic andesitic intrnsive.							

Microscopic textures (F34):

Porphyritic rock with Plagioclase and Pyroxene phenocrysts in an intergranular to pilotaxitic groundmass of feldspar, mafics and minor quartz. Common calcite as replacement/alteration of feldspar, pyroxene and groundmass. Also secondary brown iron oxide staining and oxidation of mafics.

Plagioclase is euhedral to subhedral, glomeroporphyritic, often Oscillatory zoned or sieve textured. Michel Levy on unzoned phenocrysts gives 31.5, about An 48%, Calcic Andesine, with oscillatory zoning varying between to sodic Andesine and calcic Andesine. Carlsbad Albite twinning gives 29.5, 15, about An48%. Phenocryst plagioclase is about 1–5mm in size, 35% of rock.

Groundmass plagioclase is small sub 1mm subhedral laths, in intergranular or trachytic texture, with interstitial opaques, altered pyroxenes, quartz and k-spar. ML gives: 8, 20, 16, 21, 25, 22, 19, so about An 35%, Sodic Andesine. Groundmass plagioclase probably about 20% of rock.

Pyroxene is brown to slightly yellowish clinopyroxene, often rimmed/invaded or replaced by brown iron oxides and calcite. 2v small, positive, about 25–30, so probably subcalcic augite. Up to 1mm, about 15% when calcite/iron oxide pseudomorphs are taken into account.

Remainder of groundmass is secondary calcite and alteration, with primary minerals interstitial to plagioclase microphenocrysts being anhedral quartz and k-spar, with very occasional poor granophyric texture, and fine granular altered pyroxene and magnetite making up the mafic phase. Very occasional biotite? Groundmass quartz about 15%, Groundmass kspar about 10%, groundmass opaques 5%.

Field Number		Formation:					
S5		Minor Intrusive cutting Divisadero					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
279540	4880001		9	15	51	0	75
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
20				5			
Other components:		Others:	Total:				
			100				
Final Rockname							
Andesitic or basaltic andesitic feeder dike.							

Microscopic textures (S5):

Fine grained porphyritic and mildly vesicular rock, with small feldspar phenocrysts in a pilotaxitic and intergranular groundmass of feldspar, altered mafics, trace quartz and magnetite opaques. Veins and patches of calcite occur, as does common chloritisation of mafics and secondary chlorite and quartz occur as vesicle infill.

Larger Feldspar phenocrysts are rare, 1%, up to 1mm, and are altered by sericitisation or albitisation, and often replaced by calcite. Some are zoned, with sieve texture. Were probably a sodic plagioclase.

Quartz occurs as anhedral microphenocrysts, about 5–10% 0.5mm or less, disseminated through the groundmass. Also present in vesicles as subhedral or euhedral crystals with fibrous and platy chlorite. Trace tridymite also occurs in vesicles and calcite patches.

Opaques are fine grained opaque magnetite in groundmass, partly oxidised,

Mafics are also remnant crystals of high birefringence, now mostly clay, calcite and opaques, which may have been clinopyroxene, possibly hedenbergite. 5%.

Groundmass feldspars are fine grained 0.4 to 0.1mm or so laths and smaller altered and partly recrystallised into indistinct mosaic. However, they have pilotaxitic texture with intergranular opaques, pyriboles and chlorite, plus some partly recrystallised mosaic feldspar, maybe k-spar matrix. Some crystals are albite twinned, but ML is difficult due to alteration. Angles generally less than 20 degrees, and RI both fast and slow generally below medium. Estimate groundmass to be 80%+of the rock, with about 50% albite or albitised feldspar laths, 10–15% mafics and chloritised mafics, plus maybe 15% anhedral mosaic k-spar.

Field Number		Formation:					
F46		Minor Intrusive cutting Divisadero					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
282580	4868550		15	15	60	0	90
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
5				5			
Other components:		Others:	Total:				
			100				
Final Rockname							
Plots in basalt field on QAPF, probably best described as a sub-alkali basalt							

Microscopic textures (F46):

Medium grained volcanic rock, quite different in texture from F45, the other sample from this intrusive body.

Plagioclase is about 60%, with calcic cores altered to green chloritic material and sericte. Crystals are up to 2.5mm, but most are 0.5mm. Some glomeroporphyritic. Carlsbad-Albite twinned crystal cores give 30, 11 and 32, 10 degrees, about An% 45-47, Andesine.

Pyroxene is present, about 5%, about 0.1–0.3mm, faintly green clinopyroxene in ppl. 2v about 25–30, so fairly subcalcic augite.

Opaques are fine grained, square and blocky, 0.1–0.3mm, about 5%, probably magnetite.

Quartz and low RI material, probably K-spar (presume Anorthoclase) occur in chaotic and poor granophyric intergrowth in groundmass. Probably about 10–15% each of Quartz and K-spar, with some K-spar rimming Andesine plagioclase.

Field Number	Formation:					
LH9int	Minor Intrusive cutting Divisadero					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
279098	4879268					0
Final Rockname						
Altered andesitic intrusive.						

Microscopic textures (LH9int):

Altered porphyritic rock, with phenocrysts of chloritised and altered amphibole in a matrix of sericitised and calcite replaced plagioclase, some quartz with altered opaques and secondary calcite. Prehnite, epidote and chlorite occur as alteration product of mafics, although occasional crystals of augite survive.

Field Number	Formation:					
F70B	Vent Breccia cutting Divisadero					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
281250	4869625					0
Final Rockname						
Altered Basaltic to andesitic vent breccia.						

Microscopic textures (F70B):

Altered basaltoid to andesitoid rock, porphyritic with large (up to 4mm) euhedral and subhedral altered plagioclase in an intergranular to pilotaxitic vesicular groundmass of plagioclase microphenocrysts and altered mafics, together with secondary calcite, iron oxides and quartz as alteration and void filling of vesicles.

Large plagioclase are sometimes sieve textured, and some crystals are slightly zoned. Unzoned crystal gives C-Albite of 16, 33, About An% 55, Labradorite, while section Ta gives 29, about An 48%, Calcic Andesine. Groundmass microphenocrysts are also albite twinned laths, small extinction angles, so probably more sodic, Oligoclase or Albite. Some anhedral material may be groundmass k-spar.

Mafic phase was probably Clinopyroxene, judging by the shape of the altered pseudomorphs present in calcite and opaque or brown iron oxide materials.

Opaques are magnetite, blocky and square ,altering to brown iron oxides. Both as phenocrysts and groundmass.

Common (1–3%) rounded slightly brown uniaxial negative apatite crystals as microphenocrysts. Some seem anomalously biaxial, small 2v.

Field Number	Formation:					
F70A	Vent Breccia cutting Divisadero					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
281250	4869625					0
Final Rockname						
Silicic Pumiceous Vent Breccia, devitrified and oxidised.						

Microscopic textures (F70A):

Matrix supported breccia with granule to pebble size angular clasts of devitrified felsitic pumices, andesitoid and rhyolitoid lithic fragments and crystal fragments of sodic plagioclase and bipyramidal quartz.

Matrix is opaque rich, fine grained felsitic material with extensive oxide staining, patches of calcite and perhaps siderite, semi opaque brown hematite, and rims of opaques coat clasts and crystals.

Feldspars are sodic plagioclase, replaced or altered by sericite and calcite.

About 20–25% altered pumices, 15% oxidised rock fragments, 10% crystal fragments, remaining 50% matrix of comminuted rock and crystal fragments, secondary calcite/sericite and felsitic devitrified ashy material.

A.7.3 Phonolitic Minor Intrusives

Field Number		Formation:					
L5α *		Phonolite Intrusive cutting Ibáñez					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
283980	4862235		0	30	32	25	87
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
10		2		1			
Other components:		Others:	Total:				
			100				
Final Rockname							
Phonolite or tephritic phonolite dike.							

Microscopic textures (L5α):
Porphyritic rock with glomeroporphyritic K-feldspar phenocrysts in poikilomosaic groundmass of low RI nepheline, feldspar microphenocrysts and granular aegirine and green arfvedsonite.

Feldspar phenocrysts are euhedral, 0.5–3mm crystals, , about 10%, often radially glomeroporphyritic, with some alteration to brownish sericite and clays, or replacement by mosaic k-spar, zeolite or nepheline - Low relief, colourless, low birefringence, uniaxial negative. Feldspar has Oap perp to 010, low RI, low to moderate birefringence, low (20–30) 2v, -ve, occasional remnant albite twins, particularly in microphenocrysts, but rare in larger phenocrysts. Probably about 30% Albite phenocrysts and microphenocrysts, with 5–10% anorthoclase phenocrysts and microphenocrysts, and 20 % mosaic biaxial k-spar in groundmass poikilomosaic material. Normative values used for QAPF, approx 32% Albite, 30% K-spar.

Difficult to identify groundmass mosaic material due to occurrence of k-feldspar, nepheline and zeolites (isotropic analcime and some biaxial positive zeolite?)

Groundmass is poikilomosaic texture with feldspar microphenocrysts, both albite and auorthoclase, and 10% groundmass green cpx plus about 2% green amphibole — probably arfvedsonite, surrounded in mosaic of anhedral k-spar, biaxial positive colourless, low RI mineral, possibly zeolite after Nepheline, occasional unaltered nepheline, and some isotropic analcime. Estimate originally 25 % Nepheline or so based on normative composition. ?trace biotite, 1% opaques.

A.7.4 Dacitic and Rhyolitic Minor Intrusives

Field Number		Formation:					
CP17C *		Dacite Intrusive cutting Ibáñez					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
278335	4869433		25	15	45	0	85
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
				3		5	
Other components:		Others:	Total:				
chlorite/sericite/calcite		7	100				
Final Rockname							
QAPF gives Rhyolite close to dacite boundary, Chemically dacite.							

Microscopic textures (CP17C): Porphyritic rock with euhedral to subhedral phenocrysts of quartz, chloritised biotite and sericitised plagioclase in a groundmass of felsitic material with alteration patches. Common secondary chlorite, calcite aud sericite alteration in many crystals and groundmass.

Quartz is about 10%, up to 4mm, subhedral and euhedral bipyramids and rounded embayedand occasionally skeletal crystals.

Biotite is present as altered chloritised pseudomorphs, now green chlorite with patches of calcite, or occasionally with muscovite lamellae. Originally subhedral cleavage booklets. 3–5%, up to 3–4mm.

Feldspar is subhedral and euhedral sodic plagioclase, often partly or wholly sericitised with fine grained platy muscovite, or patches of calcite, particularly in cores. About 25–30%, up to 5mm, albite twinned, RI fast and slow well below epoxy, so Albite or albitised.

Opaques are about 2-3%, mainly fine grained patchy leucoxene and occasional blocky magnetite, and pyrite was present in hand specimen.

Groundmass is about 60% of rock, fine grained to partly mosaic felsitic material, possibly slightly recrystallised, with patches of secondary calcite and chlorite, about 15% anhedral fine grained quartz/quartz mosaic, 5–7% secondary alteration as chlorite, sericite, calcite and opaques, and about 15% each of murky altered plagioclase microphenocrysts and anhedral low RI k-spar.

Field Number		Formation:					
WI43		Dacite Intrusive cutting Ibáñez					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
270507	4856660		20	16	50	0	86
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
				7			
Other components:		Others:	Total:				
uralite/chlorite		7	100				
Final Rockname							
Dacite sill.							

Microscopic textures (WI43): Porphyritic rock with phenocrysts of plagioclase, chloritised and uralitised pyroxene and blocky magnetite in a groundmass of pilotaxitic plagioclase microphenocrysts and felsitic quartz/kspar.

Plagioclase phenocrysts are about 25%, 0.2–3mm, euhedral crystals, sometimes glomeroporphyritic with slight zoning, some sieve textures in internal zones. Albite-carlsbad twins give 5, 24, about An35%, and RI both fast and slow directions above epoxy, so probably sodic Andesine. Zoned crystals have less than 1 degree change in extinction angles from core to rim, so no strong compositional zoning, rims slightly less calcic than cores.

Mafic phase occurs as blocky green pseudomorphs of pyroxene, probably after augite, now replaced by bright pleochroic green fibrous uralite or platy chlorite. Associated with magnetite and apatite in occasional clusters. Identifiable as a pyroxine by occasional euhedral octagonal end sections. About 5–7%.

Magnetite is blocky euhedral and subhedral phenocrysts and microphenocrysts, up to 0.5mm, often associated with euhedral apatite and sometimes glomeroporphyritic with the altered pyroxenes. About 6–7%.

Groundmass is about 25% fine grained sub 0.2mm pilotaxitic plagioclase microphenocrysts, with some swallowtail quench textures, and interstitial felsitic material with fine altered mafics and secondary calcite. Microphenocrysts are difficult to do ML on due to alteration, but RI is at or below epoxy, so proably oligoclase to albite. From normative composition, groundmass felsitic material is probably 20% quartz, 15–16% k-spar. Some secondary alteration to calcite and chlorite patches occur.

Field Number		Formation:					
CP48 *		Dacite Intrusive cutting Ibáñez					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
277735	4870270		18	16	55	0	89
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
			7	3	1		
Other components:		Others:	Total:				
			100				
Final Rockname							
Dacitic dike.							

Microscopic textures (CP48): Pretty Hypabyssal looking. Sparse rounded Quartz and Subhedral, sometimes rounded Sodic Plagioclase phenocrysts in a granular Quartz-K-spar-Mafic groundmass. Feldspars altered to Calcite/sericite, mafic phenocrysts(?after biotite or hornblende?) now chlorite.

Large plagioclase phenocrysts are euhedral and subhedral crystals from 2–6mm, about 10–15%, uniformly altered, replaced by patchy sericite and calcite, with some chlorite and replacement by k-spar. Probably once sodic plagioclase. Some sericite is recrystallised to platy muscovite.

Quartz phenocrysts are sparse, 1–2%, large rounded 2–4mm crystals, with slight overgrowths of groundmass mosaic quartz.

Mafic phases are altered to bright green chlorite, and are blocky or elongate 0.5–4mm pseudomorphs, which may be after biotite or amphibole, about 5%. Often in granular clusters with opaques and secondary epidote.

Some altered plagiophyric zenoliths.

Groundmass is murky, altered felsitic material with about 40% altered sodic plagioclase 0.1–0.4mm microphenocrysts, with 2–3% oxidised opaques and 1–2% chloritised mafics, some (1%) secondary muscovite, and in granular partly recrystallised interstitial felsitic material. Estimate felsitic material in groundmass 15–16% quartz, 15–16% k-spar, based on normative values.

Field Number		Formation:					
CP46A *		Dacite Intrusive cutting Ibáñez					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
277673	4870000		22	20	47	0	89
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
				1		5	
Other components:		Others:	Total:				
chlorite/sericite/calcite		5	100				
Final Rockname							
Albite-epidote facies hornfels of altered dacitic dike.							

Microscopic textures (CP46A): Coarsely porphyritic rock with altered phenocrysts of large euhedral quartz, sodic plagioclase and chloritised biotite in a felsitic to pilotaxitic feldspar groundmass, with secondary chlorite, calcite and quartz mosaic material, particularly as void filling.

About 35% phenocrysts, 65% matrix, with 10% euhedral to subhedral rounded and embayed quartz, 20% altered sericitised or saussuritised plagioclase and 5% chloritised 1–4mm euhedral biotite.

Groundmass is felsitic to intergranular murky brown altered feldspar microphenocrysts with occasional swallowtail texture, some quartz (10% or less) and common (5%) secondary chlorite, sericite, oxidised opaques and mosaic quartz as void filling. Leucoxene common (1%)

Common occurrence of epidote as granular patches in groundmass and as component of altered sodic plagioclase. Quartz phenocrysts have fine grained overgrowth from recrystallising groundmass material.

Too altered for accurate QAPF, normative composition is Q22, A20, P47.

Field Number			Formation:				
F58			Dacite Intrusive cutting Ibáñez				
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
280230	4867400		20	9	60	0	89
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
			4	5			
Other components:		Others:	Total:				
Calcite/sericite		2	100				
Final Rockname							
Dacite Hypabyssal intrusive.							

Microscopic textures (F58): Porphyritic rock with Glomeroporphryritic sericitised feldspars and green mafics, in a granular groundmass of feldspar and occasional quartz.

Quartz: 20% in groundmass.

Large feldspar phenocrysts are up to 5mm, 15–20%, euhedral and subhedral albite or sodic oligoclase, often glomeroporphyritic, generally partly sericitised and replaced with calcite in patches. RI fast and slow below medium, looks like albite or albitised.

Mafics are dark green, matted patches of chlorite/uralite which may be pseudomorphs of pyroxene and amphibole, with occurrence of both blocky octagonal and lozenge shaped pseudomorphs. About 3–4%. Chlorite also occurs in radial clusters in some feldspar glomeroporphs, 5% opaque magnetite.

Some vesicles/cavities occur, filled with calcite and lined with euhedral secondary quartz

Groundmass is granular mosaic of quartz, pilotaxitic or framework sodic plagioclase laths and murky interstitial k-spar, difficult to determine. (20% quartz, 40% sodic plagioclase, 9–10% spar, trace chlorite and mafics.) Texture partly matted or granular felsitic texture of feldspar and quartz, with some pilotaxitic patches. Some chlorite occurs as intergranular patchesl. Other minerals as alteration are Calcite, Sericite and Clay.

Field Number		Formation:				
F57B *		Dacite Intrusive cutting Ibáñez				
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
280710	4867530	28	10	55	0	93
Other componeuts:	Others:	Total:				
Altered mafics etc.	7	100				
Final Rockname						
Altered and recrystallised hybabyssal dacite.						

Microscopic textures (F57B): Porphyritic rock, with altered euhedral/subhedral rounded, glomeroporphyritic feldspars in a granular, recrystallised quartz-rich or silicified groundmass. Rock has some trails/patches of hematite/goethite iron stains running through it.

Large feldspars are about 20%, up to 5mm and are altered to sericite and replaced in patches by calcite and quartz. By remnant twinning, they were probably albite or maybe oligoclase.

Mafic phase is now sparse (3%) blocky pseudomorphs of chlorite, opaques, calcite and maybe siderite after probably pyroxene.

Groundmass is dominated by recrystallized mosaic quartz, about 30%, around remnant laths of albite, with hematite occuring in patches, replacing mafic minerals and opaques. Muscovite occurs as radial void filling material, fibrous and sericitic in some cases. Alteration products about 3–4%. K-spar difficult to estimate, but present as low RI material in mosaic groundmass.

Rock was probably a dacite, based on its textural resemblance to F58, and chemistry agrees, although significantly silicified. Normative QAPF: Q28, A10, P55.

Field Number			Formation:				
PI79A			Dacite Intrusive cutting Ibáñez				
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
275220	4873570		18	9	60	0	87
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
		5		5		1	
Other components:		Others:	Total:				
chlorite/calcite voidfill		2	100				
Final Rockname							
Dacite Dike.							

Microscopic textures (PI79A): Porphyritic rock with large (up to 6–7mm) phenocrysts of sericitised plagioclase, rounded/corroded quartz phenocrysts and green chloritised mafics (biotite and hornblende) in a fine grained felsitic groundmass.

Plagioclase phenocrysts are large, up to 6–7mm, often glomeroporphryitic or polycrystalline, euhedral and altered with spotty sericitisation, patchy k-spar networks or framework replacement and some calcite. Too altered for extinction angle methods, RI is below epoxy, so probably albite or albitised. About 40% of rock.

Quartz phenocrysts comprise about 5%, 0.5–2mm rounded and corroded subhedral bypyramids or anhedral rounded crystals. Some twinning , and often have fine cherty overgrowth of mosaic material from groundmass.

Mafic phases are altered biotite and hornblende.

Biotite, 1%, 0.5–1mm, altered to muscovite/chlorite/leucoxene/calcite, often with the muscovite optically continuous to the original biotite.

Hornblendes are elongate subhedral and euhedral chlorite pseudomorphs, up to 1mm, about 5%, uniformly altered to pale green chlorite or patchy calcite/chlorite and opaques, although may have been brown hornblende from some small remnants.

Opaques are euhedral blocky magnetite, up to 0.5mm, and fine grained disseminated leucoxene in groundmass. About 5% total.

Groundmass is partially recrystallised grainy felsitic material, with some patchy calcite and chlorite alteration and void filling 2%, and fine disseminated leucoxene and chloritised mafics.

QAPF from normative composition: Q18, A:9, P60.

Field Number		Formation:					
F59 *		Dacite Intrusive cutting Ibáñez					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
280490	4867120		22	5	60	0	87
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
				6			
Other components:		Others:	Total:				
chlorite/calcite/sericite		7	100				
Final Rockname							
Dacite Dike.							

Microscopic textures (F59): Porphyritic rock with 3–5mm feldspars, subhedral to euhedral, sometimes glomeroporphyritic, zoned, ofteu sericitised or partly replaced by clay or calcite. Large feldspars are either albite or albitised.

Quartz phenocrysts are about 5%, anhedral and sometimes mosaic voidfilling crystals, 0.5mm max. Also as mosaic material around pilotaxitic groundmass feldspars, 15–17%.

Plagioclase phenocrysts are about , 20%, 0.5–3mm subhedral and euhedral sodic plagioclase. Most crystals partially sericitised or patchy replacement to calcite. Highest ML reading: 25, An 35%, Sodic Audesine, carlsbad albite gives 12,24, An40%. Some zoned crystals down to calcic oligoclase carlsbad-albite: 5, 13, Au28%.

Large mafics are now replaced by calcite, clay, leucoxene pseudomorphs. From elongate rectangular shape, probably after pyroxene. Associated with apatite and blocky or hexagonal maguetite phenocrysts and micropheuocrysts. Altered pxne 3%, opaques 5–6%

Groundmass, Recrystallsed mosaic quartz (15–17% and maybe kspar (trace to 5%) around pilotaxitic sodic plagioclase (40%), with patches of calcite and clay, sericite. has minor secondary voidfilling quartz, common finegrained mafics. Trace chlorite, apatite. ? Trace Cristobalite. Misc Clay, Leucoxene, etc.

Looks like a dacite.

Field Number		Formation:					
F61		Dacite Intrusive cutting Ibáñez					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
280880	4866940		25	7	60	0	92
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
	4	0		4		0	
Other components:		Others:	Total:				
			100				
Final Rockname							
Hypabyssal porphyritic biotite hornblende microgranodiorite.							

Microscopic textures (F61): Hypabyssal intrusive rock, Microgranitic in texture, porphyritic with large euhedral zoned plagioclase in a matrix of microgranitic textured feldspar, quartz, biotite, amphibole and ?pyroxene. Some occurrence of pilotaxitic orientatiou of euhedral grouudmass plag.

Large plagioclase phenocrysts are euhedral, albite or carlsbad twinned, often zoned, and from RI are probably Albite at outer rims (fast and slow below epoxy and fast quartz.) Crystals are 2–4mm, 30% some with sieve textures, and outer zones on some crystals may be k-spar (?anorthoclase.) Core section Ta ou zoned crystals is +36, down to -6 degrees on the rim, giving An65% down to An15% at the rim, so zoning is ranged from Labradorite down to sodic Oligoclase, and RI indicates that some crystals are Albite at the rim.

K-spar is minor, about 5–7% as anhedral, murky altered crystals in the groundmass, and perhaps as rims on some plagioclase.

Matrix feldspar is small microphenocrysts, euhedral, carlsbad-albite twinned sodic plagioclase, ML reading about 10 degrees. RI of fast and slow well below Epoxy, so probably Albite. Sub 1mm, about 30%

Mafic minerals are high releif, colourless, low birefringence biaxial -ve ?Orthopyroxene, about 3–4%, up to 3mm, altered, and seamed with cracks and dark green chloritic and uralitic alteration and darl green-brown biotite. Brown hornblende and red-brown biotite occur as minor 0.5mm accessories associated with the orthopyroxene and opaques, trace to 0.5% each.

Opaque is maguetite, sometimes oxidised, about 3–4%. Greeu semi-opaqne alteration products of mafics abound in groundmass, pseudomorphing pyroxene. Some chloritisation of biotite.

Quartz is anhedral groundmass material, often poikilitic around partially pilotaxitic sodic plagioclase.

Field Number	Formation:					
PI86A	Minor Intrusive cutting Ibáñez					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
276170	4873100					0
Final Rockname						
Dacitic sill, altered.						

Microscopic textures (PI86A):

Section cut a bit thick. Porphyritic rock with intergranular groundmass. Phenocrysts are altered, rounded sodic plagioclase, often replaced by calcite/sericite. Some subhedral rounded quartz phenocrysts. Mafic minterals entirely replaced by chlorite, blue in cpl, and by blocky square opaqe, magnetite or pyrite. Groundmass sericitised feldspars, some unaltered sodic plag, magnetite, chloritised mafics, in intergranular texture. Some groundmass plagioclase has visibly altered calcic cores and zoning.

Field Number	Formation:					
WI98	Minor Intrusive cutting Ibáñez					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
273910	4863720					0
Final Rockname						
Altered Dacitic sill.						

Microscopic textures (WI98):

Porphyritic sill, with phenocrysts of altered ?hornblende, pseudomorphed by chlorite/calcite/leucoxene and other opaques on rim. Some quartz phenocrysts, but also secondary quartz in cavities/groundmass.

Feldspar phenocrysts altered to calcite, groundmass feldspars have recrystallised to murky mozaic quartz, some calcite and fine sericitic muscovite. Groundmass feldspars have calcite>sericite core alteration, fairly unaltered rim. Possibly Sodic plagioclase core, K-spar rims. Some Plagioclase twins still visible suggest Albite/sodic Oligoclase.

Mafics are altered entirely to chlorite/calcite/opaques, with opaques being a remnant reaction rim. Presumably these pseudomorphs were amphiboles, from their elongate prismatic sections and short stubby cross sections.

Groundmass is poikilomosaic of murky quartz mosaic, poikilitic around altered mafics and sericitised feldspars. Common patches of calcite, and also patches of fine sericitic mica.

Field Number		Formation:					
WI22 *		Rhyolite Intrusive cutting Ibáñez					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
270630	4863100		35	10	45	0	90
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
			2	3			
Other components:		Others:	Total:				
calcite/sericite/quartz voidfilling		5	100				
Final Rockname							
Rhyodacitic to rhyolitic intrusive. (Chemistry plots as rhyolite, but rock appears significantly silicified in thin section, and has no phenocryst quartz.)							

Microscopic textures (WI22):

Porphyritic rock with euhedral altered feldspars in a partly recrystallised felsitic groundmass. Some patches/void filling of mosaic quartz and calcite.

Quartz: 30–35%, mostly groundmass mosaic material, also as euhedral spar and mosaic quartz in voids with secondary calcite.

Feldspars are euhedral and subhedral plagioclase up to 4mm, 15% phenocrysts, 30% microphenocrysts in felsitic groundmass. Phenocrysts are altered and sericitised glomeroporphyritic sodic plagioclase, with some calcite and clay alteration. RI fast and slow are below medium, fast is below fast quartz. (epoxy medium is above fast quartz, about equal slow quartz.) Albite or albitised. Plagioclase laths in groundmass also albite, about groundmass K-spar estimated at 10% (difficult to tell.)

Groundmass is felsitic material with fine disseminated chloritised mafics, sericite and some recrystallisation to mosaic quartz/felspar. Common secondary clear mosaic quartz occurs as void filling. Opaques are magnetite, often altered to leucoxene. Also 1–2% fine chloritised mafics. Trace apatite, trace Tridymite.

Other minerals: Calcite, sericite, hematite, leucoxene, as alteration (5-7%) also traces of tridymite, Apatite, Magnetite (2–3%).

Field Number WI10 *		Formation: Rhyolite Intrusive cutting Ibáñez					
Utm East 276460	Utm North 4863460		Q: 25	A: 10	P: 60	F: 0	Subtotal: 95
Cpx:	Opx:	Amph:	Chlorite:	Opaques: 1	Muscovite:	Biotite: 2	Olivine:
Other components: Calcite, etc.		Others: 2	Total: 100				
Final Rockname Rhyolitic sill.							

Microscopic textures (WI10):

Microporphyritic rock, with microphencrysts of feldspar, quartz in a matted feldspathic groundmass, partly trachytic and partly felsitic in texture.

Phenocryst Plagioclase occurs as murky, partly sericitised euhedral crystals up 3mm long, sometimes glomeroporphyritic, 8–10%. ML test not feasible, but looks like Sodic plagioclase. RI tests: Fast dir. Plagioclase below Glue, Slow dir above, so looks like An15% or lower — Sodic Oligoclase or Albite.

Quartz occurs as small anhedral crystals, apparently phenocrysts, but often displaying triple-junction boundaries and no apparent volcanic style bipyrimids. I think most quartz in this rock, both microphenocryst size and groundmass recrystallisation mosaic may be secondary recrystallisation textures. Some quartz in calcite patches shows euhedral vein quartz shapes. About 20–25%.

Sparse mafics, some up to 1.5mm, but mostly small fibrous material in groundmass, are biotite, partially or entirely altered to chlorite (1–2%)

Calcite occurs in patches in groundmass: also within altered amphibole and plagioclase. 1% opaques.

Groundmass has also recrystallised into a quartz "poikilomosaic" type texture around what was probably a feldspathic trachytic groundmass. Some remnant biotite is present, but most appear altered to chlorite. Groundmass feldspars are subhedral pilotaxitic 0.1–0.2mm laths, albite twinned, extinction angles below 10, RI below medium, albite, about 50%. Estimate 10% k-spar in recrystallised patches with quartz, based on normative k-spar content.

Field Number F14 *		Formation: Rhyolite Intrusive cutting Ibáñez					
Utm East 289762	Utm North 4869589		Q: 43	A: 14	P: 37	F: 0	Subtotal: 94
Cpx:	Opx:	Amph:	Chlorite:	Opaques: 2	Muscovite: 2	Biotite: 2	Olivine:
Other components:		Others:	Total: 100				
Final Rockname Slightly altered and recrystallised Hypabyssal rhyolite. (Hypabyssal more to field outcrop pattern and large phenocrysts than anything else. Could be a post-Ibáñez dome root or dike.) TAS definition is Calk-alkaline rhyolite.							

Microscopic textures (F14):

Porphyritic rock with quartz, feldspar and altered biotite phenocrysts in a granular felsitic matrix.

Quartz phenocrysts are sparse, 1–5%, large, up to 6–10mm, rounded subhedral beta quartz, sometimes twinned, often embayed or fractured. Some crystals have slight overgrowths from recrystallised matrix material, optically continuous but murkier than original phenocryst. Embayments often contain sericite, calcite or felsitic matrix material.

Plagioclase phenocrysts are euhedral to subhedral, rounded, up to 3mm, but sometimes in glomeroporphyritic clusters 6mm across, about 10%. Twinning when visible is albite or albite-carlsbad, but often very poor due to alteration. Feldspars also have recrystallisation/reaction rim with felsitic matrix and are murky with small patches of hematite, sericite and calcite. RI calibration: Medium is above fast quartz, almost equal slow quartz. Feldspar has fast and slow well below medium, albite.

Biotite is in euhedral booklets, up to 2mm across, 1–2%, but is entirely altered to muscovite of the same optical orientation with lamellae of opaques between cleavages, with the opaques being either brown goethite or leucoxene, or both. Traces of euhedral to subhedral Apatite crystals occur in close association with the biotite pseudomorphs.

Groundmass is 80+% of rock, of fine grained granular felsitic material, slightly recrystallised in places, especially around some quartz phenocrysts, with disseminated fine platy sericitic mica (1–2%), patches of oxidised opaques, 2%. RI movement of becke lines indicates 2 minerals at least in felsitic material, although mostly quartz mosaic.

QAPF difficult due to fine matrix, normative numbers are Q43, A14, P37.

Field Number		Formation:					
F12 *		Rhyolite Intrusive cutting Ibáñez					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
289954	4871335		38	25	30	0	93
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
				2		1	
Other components:		Others:	Total:				
Calcite/sericite altn.		4	100				
Final Rockname							
Devitrified and recrystallised rhyolitic intrusive.							

Microscopic textures (F12):

Porphyritic rock, with large, up to 5mm glomeroporphyritic rounded euhedral feldspars and 1–2mm euhedral green-brown biotites and embayed, rounded 1–2mm euhedral beta quartz, in an equigranular matrix of coarse felsitic or microgranular quartz and feldspar.

Quartz: 5–8 % phenocrysts and microphenocrysts, up to 3mm, euhedral bipyramids.

Large Feldspars are euhedral, glomeroporphyritic Albite-carlsbad twinned, with some sericitisation and replacement by calcite. RI is less than medium, and well below groundmass mosaic quartz, so looks like Albite. 5%, up to 4mm.

Biotite is euhedral booklets, green-brown pleochroic, sometimes with associated apatite, often partly chloritised and seamed with leucoxene along some cleavage planes. 1%, euhedral, up to 2mm. Musxovite Trace, as sericite and alteration of biotite. Chlorite also trace, as alteration of biotite.

Opaques: Altered blocky or anhedral hematite and leucoxene, up to 1mm, 1–2%.

Secondary calcite, platy sericitic mica, as replacement of feldspar and groundmass.

Groundmass was felsitic texture, recrystallised to coarse and granular mosaic qnartz and murky altered feldspar. 80–85% of the section. About 30% mosaic quartz, estimate about 25% each plagioclase and k-spar. Some apatite occurs in gmass.

Field Number		Formation:					
WI17 *		Trachy-dacite Intrusive cutting Ibáñez					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
273920	4864910		12	8	65	0	85
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
		10		5			
Other components:		Others:	Total:				
			100				
Final Rockname							
Trachy-Dacite.							

Microscopic textures (WI17):

This rock is very similar to WI15. A porphyritic rock with phenocrysts of plagioclase and hornblende in a granular feldspar-quartz-mafic groundmass.

Hornblendes are 1-5mm euhedral to subhedral phenocrysts, completely altered to chlorite, calcite, opaques, but with good pseudomorphing of crystal shape and cleavages. Reaction rims of opaques around the hornblende pseudomorphs are very well developed, and probably represent corrosion while in magma.

Plagiocase is euhedral-subhedral, glomeroporphyritic, carlsbad-albite twinned, well sericitised and zoned. Carlsbad Albite test gives: 14, 31.5 — An48% - Andesine, but many crystals appear to have been albitised.

Groundmass dominated by granular felsitic texture, with tablets of plagioclase, maybe some k-spar, with interstitial quartz, and some chloritised and uralitised hornblendes.

Proportions, Plagioclase phenocrysts, 30%, Hornblende, 10%, groundmass remainder, of approx 10–12 %quartz, 5–8% k-spar , 35% plagioclase, 5% opaques, 10% chloritised hornblendes. Patches of Calcite occur. Chemically this rock plots as a Trachyte, but I feel that it is most likely an andesite or dacite, as is WI15.

Field Number		Formation:					
F44A *		Dacite Intrusive cutting Coyhaique Group					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
282980	4868520		20	10	60	0	90
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
4				6			
Other components:		Others:	Total:				
			100				
Final Rockname							
Hypabyssal dacite intrusive.							

Microscopic textures (F44A): Porphyritic rock with partially altered phenocrysts of sodic plagioclase and magnetite in a groundmass of quartz and plagioclase microphenocrysts in pilotaxitic texture altered to poikilomosaic texture by recrystallisation, with traces of apatite and secondary hematite staining.

Plagioclase phenocrysts are about 20%, euhedral, sometimes glomeroporphyritic crystals from 1–4mm, partially altered with patchy replacement by cherty textured k-feldspar and calcite along fractures and cleavage planes, and some sericite. RI of phenocrysts has fast below epoxy and slow just below or equal, so albite or albitised.

Magnetite phenocrysts are subhedral to euhedral 0.5–1mm crystals, about 1%, altered to opaque hematite and some leucoxene.

Mafic phase is blocky, rectangular pseudomorphs in calcite of ?pyroxene, up to 2mm, about 3–4%

Groundmass is felted mass of pilotaxitic sodic plagioclase laths, probably albite, but partially mosaic recrystallised to poikilomosaic texture, about 40% plag, 4–5% fine oxidised mafics and opaques, trace apatite, 20% subhedral quartz microphenocrysts/mosaic quartz, and 10% interstitial k-spar.

Field Number		Formation:					
F40 *		Trachy-dacite Intrusive cutting Coyhaique Group					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
284100	4868880		15	8	65	0	88
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
5				6			
Other components:		Others:	Total:				
Apatite		1	100				
Final Rockname							
Hypabyssal Dacite/trachydacite intrusive.							

Microscopic textures (F40):

Porphyritic rock with phenocrysts of altered euhedral sodic plagioclase and green uralitised or chloritised mafics, with microphenocrysts of quartz, in a finegrained matrix of quartz/feldspar with both pilotaxitic and poor granophyric textures.

Plagioclase is euhedral to subhedral altered crystals, 0.5–3mm, 20% some glomeroporphyritic clots upto 6mm, with altered mafics and opaques. Crystals are murky and sericitised, albite and carlsbad twinned remnants give poor readings of 13, 20, and 16, 21, about An 35–38%, Andesine.

Quartz phenocrysts 1–3mm, about 3%, are subhedral bipyramids or anhedral, and both are often serated or skeletal at their rims, and may have network granophyric overgrowths/rims with groundmass feldspar.

Mafic phase is mainly uralitised blocky euhedral clinopyroxene pseudomorphs, altered to chlorite, maybe some uralite, up to 3mm, 4–5%, identified by octagonal and square-ish end sections and by one remaining partially uralitised crystal with augite range clinopyroxene interference colours. In naked eye view of thin section matrix around mafics has pale alteration halo, which seems to be optically continuous quartz recrystallisation patches in thin section.

Opaques are blocky magnetite phenocrysts and microphenocrysts, up to 1mm, about 5–6% Also trace to 1% apatite.

Groundmass is about 40–45% sodic plagioclase microphenocrysts, 3–5% opaques and uralitised/chloritised pyroxenes, trace chloritised biotite (often included within feldspars or late stage in voids.) remainder is about 12% granophyric quartz intergrown with about 5–8% murky, low RI anhedral K-spar.

Field Number	Formation:					
CF13E	Minor intrusive cutting Ibáñez and Divisadero					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
273179	4877563					0
Final Rockname						
Altered rhyodacitic to Rhyolitic Dike.						

Microscopic textures (CF13E):

(This section may be cut a little thick, with some strongly yellow quartz.) Moderately altered porphyritic rock, with phenocrysts of Sodic Plagioclase, Quartz and altered ?amphibole in a fine grained equigranular felsitic to mosaic quartz/feldspar groundmass.

Quartz is about 2–5%, rounded euhedral and subhedral bipyramids, from .4–3mm. Some embayments and skeletal crystals.

Feldspar phenocrysts euhedral and subhedral glomeroporphyritic sodic plagioclase, between 1 and 5mm, up to 20%. Alteration includes cracking/fracturing with clay alteration, some sericite and occasional saussurite alteration to cores, but in general these feldspars are less altered than those in the other CF13 intrusives. Crystals are zoned and albite-carlsbad twinned, but not well enough for extinction angle methods. RI varies between Albite to K-spar, (fast and slow both below medium) and Albite/Sodic Oligoclase (fast and slow stradling medium.).

Mafics are green to brown partly chloritised elongate crystals of amphibole 1–3%, 1mm or less, probably green-brown hornblende. Some may be uralitised. Subhedral, no good cleavage seen. Alteration may include opaque reaction rims, chlorite, quartz, epidote, uralite and calcite.

Groundmass is fine grained granular felsitic or mosiaic equigranular quartz and feldspar with murky patches of clayey and sericitic alteration. Microphenocrysts of magnetite and perhaps secondary pyrite occur.

Field Number	Formation:					
CF13C	Minor intrusive cutting Ibáñez and Divisadero					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
273179	4877563					0
Final Rockname						
Altered rhyolitic dike.						

Microscopic textures (CF13C):
Very similar to CF 13B, altered porphyritic rock, with euhedral sericitised and glomeroporphyritic feldspars, chloritised mafic phase and calcite/sericite alteration of a felsitic groundmass. However, quartz is more common, about 5%, 0.1–4mm rounded and embayed crystals.
Feldspars are completely altered, now pseudomorphs of sericite, calcite and ?leucoxene.
Mafics are difficult to identify, but long shape probably indicates amphibole, hornblende like CF13B, also chloritised and perhaps some are uralitised (not quite straight extinction, no blue int. colours.
Groundmass is felsitic quartz/feldspar, but with about 5% of subhedral quartz microphenocrysts. Sericite, calcite and chlorite common.

Field Number	Formation:					
CF13B	Minor intrusive cutting Ibáñez and Divisadero					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
273179	4877563					0
Final Rockname						
Altered dacitic intrusive.						

Microscopic textures (CF13B):
Highly altered porphyritic rock, with all phenocryst phases altered bar quartz.
Feldspars were euhedral sodic?plagioclase, now with near complete alteration to sericite, and in some cases clays and calcite. Some were glomeroporphyritic with mafic minerals.
Mafic phase is now altered to green chlorite, blue interference colours, although some may be uralitised. From long crystals and 60/120 end sections, these were hornblendes.
Groundmass is fine grained felsitic material, with common secondary chlorite, sericite and calcite, sometimes studded with euhedral pyrite. Leucoxene also occurs as an alteration product of both opaques and mafics.

Field Number		Formation:					
F47		Dacite Intrusive cutting Divisadero					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
281980	4868360		25	3	55	0	83
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
			12	5			
Other components:		Others:	Total:				
			100				
Final Rockname							
Dacite dike.							

Microscopic textures (F47): Porphyritic rock with phenocrysts of sericitised sodic plagioclase and chloritised/uralitised mafic phase, probably hornblende, in a groundmass of fine grained pilotaxitic feldspar and anhedral or bipyramidal quartz microphenocrysts, with fine grained opaque magnetite, secondary calcite, green pyriboles, apatite & chlorite.
Plagioclase phenocrysts are up to 2 or 3mm, about 10%, euhedral, sometimes glomeroporphyritic with altered mafics and euhedral opaque magnetite. Most crystals have patches of calcite, sericite, or patchy, skeletal dissolution texture?. Altered C-Albite twins gives 14, 20, about An35%, Sodic Andesine, however, RI test of altered crystals at the edge of slide gives RI both fast and slow below epoxy. Poor section Ta gives 12 degrees, about An20%, Oligoclase.
Occasional opaque square euhedral magnetite phenocryst and blocky rectangular altered mafics, now fibrous or amorphous green chlorite or uralite. 2%
Groundmass is pilotaxitic fine grained sodic plagioclase microphenocrysts with interstitial felsitic textured quartz/feldspar, with disseminated fine opaques and green pyriboles, often chloritised. Patches of calcite and chlorite occur. Also microphenocrysts of rounded quartz and occasional plates of tridymite, plus apatite. From unaltered groundmass areas, original ratio about 45% fine grained plagioclase, 20–30% mosaic and microphenocryst quartz,mabye 3–5% k-spar, 10% green chloritised mafics and 5% opaques and traces of zircon, apatite, tridymite, and quartz, epidote, calcite, chlorite, sericite as void filling and alteration products.

Field Number		Formation:					
F64B *		Trachy-dacite Intrusive cutting Divisadero					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
281130	4868670		15	10	62	0	87
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
4			3	5			
Other components:		Others:	Total:				
apatite		1	100				
Final Rockname							
Quartz trachyte dike, Trachyte by chemistry. (much of the quartz looks like secondary recrystallisation.)							

Microscopic textures (F64B):
Trachytic textured rock with large phencoryst phase of euhedral Carlsbad-albite twinned, altered sodic plagioclase.
Large feldspars have moderate 2v, 40–60 ish, ML angles all below 10 degrees and RI fast well below epoxy, slow slightly below, so probably albite. About 10–12%, up to 5mm, euhedral crystals, sometimes glomeroporphyritic.
Quartz occurs as anhedral microphenocrysts or mosaic polycristalline patches, and also some very low RI uniaxial negative cristobalite occurs with it. Up to 5%, 0.4mm.
Mafic phase are small blocky pseudomorphs of calcite, chlorite, semi-opaque goethite/hematite, probably after pyroxene, 3–4%. Associated with magnetite and apatite (1%).
Opaques are blocky magnetite, 5%, up to 1mm. Associated with apatite and altered pyroxene.
Groundmass is approx 50% fine grained pilotaxitic feldspar, with intergranular textured opaques and 2–3% green alteration product, presumably chlorite after pyroxene. Feldspar is fine narrow albite laths, with RI just below epoxy glue, with some poikilomosaic texture formed by groundmass quartz and k-spar. Estimate 10% k-spar and 10% mosaic quartz.

A.8 Granitoids and Microgranitoids

Field Number	Formation:					
CF15B	Cerro Farellón Granitoid					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
272100	4878970					0
Final Rockname						
Thermally altered Dacitoid to rhyolitoid dike.						

Microscopic textures (CF15B): Altered porphyritic rock, with phenocrysts of saussauritised plagioclase, rounded bipyramidal quartz and chloritised mafics in a partly altered and recrystallised felsitic groundmass.
Quartz is unaltered, subhedral rounded and embayed crystals, 1–4mm, 5% or less. Some may have slight rim of secondary recrystallisation of calcite, quartz and chlorite from groundmass.
Feldspar is murky, saussauritised euhedral-subhedral glomeroporphyritic plagioclase, up to 6mm, with crystals partly or wholly replaced by epidote, sericite, calcite and albite.
Mafic was biotite, possibly xenocrystic, as one large crystal is present, replaced by bright green chlorite, ?calcite and opaque white leucoxene.
Smaller patches of chlorite within groundmass may indicate replacement/alteration of fine grained mafic, either hornblende or biotite. Not easily discernable pseudomorphs.
Matrix is altered felsitic to partly pilotaxitic, poorly flowbanded quartz-feldspar material, with secondary sericite, calcite, chlorite and quartz recrystallisation to mosaic quartz/feldspar around edges of granitic xenolith/block and around some quartz phenocrysts and within some cavities.
Opaques are leucoxene, ?magnetite and perhaps pyrite.

Field Number		Formation:					
CF15 *		Cerro Farellón Granitoid					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
272100	4878970		20	10	55	0	85
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
		7		3		5	
Other components:		Others:	Total:				
			100				
Final Rockname							
Biotite-Hornblende micro granodiorite.							

Microscopic textures (CF15): Crystalline, granitic rock, with plagioclase dominant over quartz, and quite euhedral as well. Plagioclase is controlling textural element, with interstitial later phase quartz, biotite (chloritised) and green hornblende. Opaque is magnetite, and epidote occurs as a late stage or secondary mineral.
Plagioclase is subhedral-euhedral, up to 3mm crystals, about 50–55%, controlling textures strongly. Crystals are oscillatory zoned, and some may have au outer rim of orthoclase. Carlsbad albite twinning on one crystal core gives 5, 20, about An 30, Oligoclase-andesine boundary. Another, 20, 32, gives An56-ish. Looks like zoning from Andesine to Oligoclase, sometimes repeated several times, and some maybe with a late stage outer rim of orthoclase, through which albite twins do not propagate. Some crystals have either cores or zones partly sericitised.
K-spar — ? Trace to 5–10% as orthoclase rim on some plagioclase.
Quartz is anhedral, irregular crystals, late stage and interstitial to the plagioclase. About 15–20%.
Mafic phase is 5–8% pleochroic green amphibole and 5% partly chloritised green-brown biotite. Crystals are subhedral or anhedral, with biotite altered to bright green with purple cpl color chlorite, and amphibole often altered to chaotic green uralite or uralite/chlorite mix.
Trace minerals include, 3–4% magnetite, trace secondary epidote, sericite in feldspars, maybe trace leucoxene, plus apatite trace with mafic phases.

Field Number		Formation:					
CF10		Cerro Farellón Granitoid					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
274091	4875954		20	8	60	0	88
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
			5	5			
Other components:		Others:	Total:				
epidote,apatite, zircon		2	100				
Final Rockname							
Could be referred to as hypabysal micro-granodiorite, or perhaps as a coarse grained subvolcanic dacitic intrusive.							

Microscopic textures (CF10): Rock is porphyritic, with euhedral large plagioclase in a granular groundmass of sericitised euhedral/subhedral sodic plagioclase and fine mosaic anhedral quartz, with green chloritised mafics. Rock looks distinctly hypabyssal in texture. (Similar in texture to the sample from the top of Cerro Pirámide.)

Large plagioclase is euhedral, sometimes glomeroporphyritic, but smaller plag is subhedral, equigranular and often hypidiomorphic with quartz and mafics. All plagioclase is partly sericitised and many are zoned. RI of large plagioclase is fast below medium, slow above, so it looks to be oligoclase to andesine. Twinning is indistinct, due to sericitisation. About 60%, oligoclase to andesine, euhdral to subhedral, bimodal.

K-spar occurs as anhedral groundmass mosaic crystals, about 5-8%, sometimes intergrown with quartz.

Quartz is mostly small, 0.1–0.4mm about 20% anhedral, granular or mosaic crystals interstitial to smaller plag, but some larger, subhedral crystals do occur. Some larger crystals are slightly granophyric at rims with k-spar.

Mafics are altered to pleochroic green chlorite (4–5%)and some muscovite, with also magnetite altering to leucoxene (5%). Chlorite is purple in cpl. Magnetite also occurs with some of these altered mafics, as does some apatite, zircon and yellow-green epidote.

Some large patches of sericitic mica occur, which may be entirely altered feldspars.

Field Number		Formation:					
CF6B		Cerro Farellón Granitoid					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
271799	4881025		20	10	55	0	85
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
		7		6			
Other components:		Others:	Total:				
Epidote/titanite/calcite		2	100				
Final Rockname							
Hornblende granodiorite.							

Microscopic textures (CF6B): Hypidiomorphic, but slightly porphryitic with large subhedral to euhedral plagioclase looking in some places.

Quartz is about 15–20%, up to 2mm, anhedral, interstitial to most other minerals, often slightly granophyric with murky altered k-spar.

Plagioclase dominant phenocryst phase, 50–55% 0.25 to 4mm, sub and euhedral, sometimes zoned, some synneusis twinning. RI seems to be above medium, but strongly below omega quartz, Sect Perp A gives 22, so An35 ish, but based on RI, Oligoclase also occurs. 2v close to 90. Some plagioclase sericitised in cores, and occasionally slightly saussuritised with some albitisation and epidote.

K-spar present as anhedral, murky low RI interstitial crystals to plag and quartz, sometimes in granophyric intergrowth with quartz, small 2v. About 10%.

Mafic phase is pale green pleochroic hornblende,.5–2mm, 7–8%, sometimes altered to fibrous chlorite or platy fibrous uralite.

Opaques are blocky magnetite, 0.1–0.5mm, about 5–6%, associated with amphiboles.

Trace Calcite. Trace Epidote, assoc with altered plagioclase and hornblende and opaques, also some titanite.

Field Number		Formation:					
CF6A		Cerro Farellón Granitoid					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
271799	4881025		20	8	60	0	88
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
		6	1	5			
Other components:		Others:	Total:				
			100				
Final Rockname							
Hornblende granodiorite.							

Microscopic textures (CF6A): Bimodal porphyritic granitic texture with large euhedral plagioclase up to 4mm, in a matrix of fairly equigranular euhedral-subhedral plagioclase and anhedral green hornblende and quartz. Smaller material is 0.1–0.5mm or so.

Plagioclase is 0.5–3mm, 55–60% plagioclase with large euhedral crystals in a granitic matrix of smaller plag/quartz/mafics. Ab-C: (22, 7), (25,12) gives An 45–50%. ML of smaller population: 20, 19, 22, 6.58.5, 20,7. Gives An 42%, so Andesine, with large crystals slightly more calcic than smaller later crystals. Some sericitisation.

Kspar is rare, if present at all, perhaps ?Trace to5–8%, anhedral, altered grains interstitial to small plag.

Quartz is Sub 1mm, 15–20%, anhedral, interstitial to smaller plagioclase.

Green hornblende is about 5–6%, 0.025–0.6mm, pale pleochroic green subhedral crystals, often altered to uralitic material mixed with chlorite Chlorite is present as Trace-1% as alteration of mafics. Purple in extinction. Pale green pleochroic.

4–5% subhedral granular opaques, mainly magnetite, up to 0.5mm. Trace Epidote, fine grained alteration product. Also some Calcite or perhaps other carbonate.

Field Number		Formation:					
CF16 *		Cerro Farellón Granitoid					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
272210	4879050		20	10	60	0	90
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
		3		4		3	
Other components:		Others:	Total:				
			100				
Final Rockname							
Partly sericitised I type hornblende-biotite micro-granodiorite.							

Microscopic textures (CF16): Very similar to CF 15, but significantly more altered. Plagioclase rich granitic rock with subhedral-euhedral plagioclase, partly sericitised, and with interstital quartz, green hornblende and chloritised biotite.

As with CF 15, Plagioclase is euhedral-subhedral crystals, 55–60 % up to 4mm, which control the texture of the rock, almost cumulate. Sericitisation is more common, with many crystals showing partial sericitisation. Crystals are zoned, some simple, some oscillatory, and some may have an orthoclase K-spar outer rim. Ml on cores gives: 9, 20, 31.5, 24, 30.5, about An54%, Andesine. Rims are more sodic, down to Oligoclase and perhaps K-spar outer rim. Poor albite carlsbad measurement also gives Andesine for cores.

K-spar, 5-10% as rims and minor interstitial phase to Plag.

Quartz is anhedral to subhedral, interstitial to euhedral plag, 0.1–2mm, 15–20%. Some euhedral crystals overgrown by mafics.

Mafic phases are green hornblende and green chloritised biotite, about 3% hornblende and 3–4% biotite. Chlorite replaces biotite, together with some leucoxene.

Magnetite occurs, about 3–4%

Other minor phases: Apatite, Titanite, late or secondary epidote.

Field Number		Formation:					
CF19C *		Cerro Farellón Granitoid					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
271642	4878393		4	10	57	0	71
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
		15	10	4			
Other components:		Others:	Total:				
			100				
Final Rockname							
Hornblende Hornfelse facies basic xenolith in Cerro Farellón Granitoid.							

Microscopic textures (CF19C): Altered basic rock, with poorly preserved feldspars and chloritised mafics in granular texture, maybe some remnant phenocrysts but difficult to tell due to alteration. Strong reaction rim with granitoid, with growth of radial and granular green tremolitic amphibole.

Feldspars are up to 2mm, euhedral relict phenocrysts of plagioclase, rare, otherwise altered groundmass feldspar sub 0.5mm, murky and clayey.RI fast and slow is less than epoxy, possibly Albite, about 50–55%.

Mafic phases are altered to green chlorite (10%) and radial clusters of pleochroic green tremolitic amphibole (15–20%).

Opaques are now pyrite, also some anhedral leucoxene, about 4–5%.

Interface with granitoid has slightly coarser grainsize, before giving way to large, unaltered euhedral zoned plagioclase in porphyritic texture with matrix of felsitic material and occasional green hornblende. Plagioclase phenocrysts in microgranitoid are up to 5mm, euhedral, cracked and altered around rims. Amphibole also has reaction rims, and also occurs as sparry growths in vesicles or miarolitic cavities.

QAPF not feasible by mineral estimation, Normative results are approx Q4,A10,P57.

Field Number		Formation:					
CF20		Cerro Farellón Granitoid					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
272387	4878345		25	8	55	0	88
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
				4		5	
Other components:		Others:	Total:				
sphene/epidote/apatite/zircon		3	100				
Final Rockname							
I type Biotite Microgranodiorite, maybe microtonalite, if enough plag.							

Microscopic textures (CF20): Very similar mineralogy to the other Cerro Farellón granitoids. Bimodal rock with large subhedral Plagioclase dominant, with interstitial equigranular quartz, and late stage green brown biotite, some chloritised, and magnetite, epidote, apatite, zircon as trace minerals. No amphibole, though.

Plagioclase is a little less euhedral than other samples, more subhedral, and less size difference between plagioclase and quartz. Up to 2mm crystals, about 50–55% of rock. Crystals are subhedral, some euhedral, often partially zoned, and some sieve texture present. Some crystals are partially sericitised, especially core regions, or more calcic zones. Carlsbad-albite gives 12,25 — An40, in cores, slightly more sodic towards rims. Andesine.

K-spar not immediately noticeable, maybe 5–8% , mainly as low RI rims to plagioclase and fine slightly murky low RI crystals interstitial to plagioclase and quartz in groundmass.

Quartz is anhedral to subhedral 0.1–1mm crystals, interstitial to plag, fairly equigranular but with some larger more anhedral crystals of similar nucleation age to the plagioclase, smaller crystals more euhedral, granular of later nucleation. About 25–30%.

Biotite, brown to greenish brown is up to 1mm, but most anhedral clusters of booklets about 0.1mm, is interstitial to quartz and associated with later stage opaques and also with finely granular plagioclase xenolithic or refractory material. About 5%, some altered to chlorite.

Trace minerals include titanite, epidote, magnetite (3–4%), apatite, maybe zircon.

Field Number	Formation:					
CF5	Cerro Farellón Granitoid					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
274338	4876679					0
Final Rockname						
Hydrothermally altered and saussuritised hypabyssal dacitiod-rhyodacitoid.						

Microscopic textures (CF5): Porphyritic rock with saussuritised plag, rounded beta quartz and altered green/brown hornblendes in matrix of fine grained mosaic quartz/altered feldspar, calcite, sericite, epidote and chlorite.

Essentially the same intrusive as CF1-2, but with saussuritisation being the dominant alteration method.

Field Number		Formation:					
CF25 *		Cerro Farellón Granitoid					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
272151	4878035		25	10	50	0	85
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
				6		8	
Other components:		Others:	Total:				
epidote, apatite,zircon		1	100				
Final Rockname							
Porphyritic quartz microgranodiorite.							

Microscopic textures (CF25): Rock is very similar in texture to CF24, but with less coherent, more altered groundmass. Porphyritic, with large, euhedral and zoned plagioclase feldspars, in a granular to chaotic felsitic altered groundmass of biotite, brown pyriboles, altered feldspar and quartz.

Plagioclase is euhedral to subhedral, sometimes oscillatory zoned, often glomeroporphyritic. Crystals are up to 4mm, largest clusters 10mm, about 40% phenocrysts and within groundmass about 10%, so 50% total. Many crystals, especially smaller ones, have cores altered to sericite. ML on unaltered cores and unzoned crystals: 35, 17, 23, 24.5, 28.5, 9.5, 24.5, and C-A 9, 24. Gives An 60 by ML and An 38 by CA. Zoning appears to oscillate between these approx compositions.

K-spar not obvious, but may be present within chaotic quartz mosaic in groundmass as felsitic material. 5–10%

Quartz is less common than CF24, 20–25% not present as larger crystals, but common as anhedral mosaic crystals in groundmass, with many inclusions and flaws. Perhaps a sort of messy micro-granophyric texture.

Biotite is green-brown, small clusters up to 1mm, about 5–8% altered to brownish mineral, small, platy, and some to chlorite. Some zircon and apatite occurs with altered biotite.

Accessory minerals include epidote, opaque is magnetite, at trace to 5-6%

Widespread alteration to sericite occurs, of both plagioclase crystals and groundmass material.

Field Number		Formation:					
CF26 *		Cerro Farellón Granitoid					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
272103	4882481		20	10	60	0	90
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
		4		4		2	
Other components:		Others:	Total:				
			100				
Final Rockname							
Biotite-hornblende quartz monzodiorite. I type.							

Microscopic textures (CF26): Equigranular granitic rock with dominant euhedral-subhedral plagioclase, interstitial quartz and mafic phases of green-brown hornblende and chloritised green-brown biotite, minor K-spar, probably orthoclase.

Plagioclase is euhedral to subhedral, between 0.5 and 4mm, about 60%. Carlsbad-albite twinning gives: 13, 25.5 (Core, rim slightly more sodic.) About An 46%. Additional reading: 12, 27.5, About AN 50%. Some plagioclase is partly zoned, oscillating once or twice, with core and rim about the same with an intemediary more sodic zone, but varying only in about 5 degrees extinction angle. Some sericitisation, but not pervasive.

K-spar is trace to 5–10%, small, anhedral crystals, biaxial positive, moderate 2v, interstitial to plagioclase and often to quartz, sometimes in granophyric intergrowth at rims of quartz. Orthoclase.

Quartz is anhedral, interstitial to the Plag, about 15–20%, up to 2mm, sometimes slightly granophyric with k-spar at edges.

Hornblende is green-brown, sometimes chloritised or uralitised, with crystals up to 3mm, but most sublmm. About 4–5%.

Biotite is brown to green brown, but commonly chloritised to bright green pleochroic chlorite with purple-blue interference colours. About 2%.

Accessory minerals include epidote, trace zircon, magnetite opaque (4–5%).

Field Number		Formation:					
CF27 *		Cerro Farellón Granitoid					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
272468	4882333		28	20	45	0	93
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
		3		3		1	
Other components:		Others:	Total:				
			100				
Final Rockname							
Porphyritic microgranular hornblende micro-monzogranite.? I type, hypabyssal.							

Microscopic textures (CF27): Porphyritic rock with subhedral to euhedral crystals of plagioclase, some K-spar and plus hornblende and sparse biotite in a an equigranular or granulitic matrix of quartz and ?K feldspar.

Plagioclase. Large plagioclase phenocrysts are up to 4mm, about 30%, and are euhedral to subhedral, with slight zoning. Some have reaction rims or "framing" where groundmass granular quartz and k-spar have nucleated. Albite Carlsbad twinning gives: 26.5, 11.5, About An 48%. Smaller subhedral to anhedral more sodic crystals occur in groundmass, 10–15%, some with k-spar rimming

K-spar. Occasional subhedral large phenocryst up to 4mm occur, but most crystals are small, anhedral mosaic material with quartz as part of the granular groundmass. Large crystals have partial overgrowth of optically continous smaller crystals in surrounding groundmass. 20% ish.

Quartz is mostly fine 0.1–0.2mm anhedral groundmass crystals, sometimes granophyric, but generally anhedral granular crystals with k-spar. but occasional rounded phenocryst with an optically continous groundmass quartz overgrowth occurs. About 25–28%.

Hornblende is subhedral, 0.4 to 5mm crystals, sometimes chloritised or uralitised, about 3%

Biotite is rare, with reaction rims and chloritisation around edges, and is poikilitic about small plagioclase. Opaques are 2–3%, blocky magnetite associated with hornblende.

Field Number		Formation:					
CF41B		Cerro Farellón Granitoid					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
273233	4882541		10	5	75	0	90
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
		5		4			
Other components:		Others:	Total:				
epidote/apatite		1	100				
Final Rockname							
Hypabyssal Porphyritic quartz micro-diorite or micro tonalite, depending on amount of quartz in layers derived from interaction with granitoid.							

Microscopic textures (CF41B): Xenolith/Enclave: A porphyritic rock with euhedral glomeroporphyritic plagioclase, subhedral and sometimes uralitised green/brown amphibole, perhap trace pyroxene, chloritised, in a groundmass of pilotaxitic sodic plagioclase, perhaps k-spar and intergranular magnetite, chloritised and uralitised pyriboles and some quartz-hornblended mosaic recrystallisation or blebs of granitic material. Secondary epidote occurs as part of alteration of some plagioclase.

Plagioclase phenocrysts are about 15–20%, up to 5mm, sometimes glomeroporphyritic, partly saussauritised. Some display mild oscillatory zoning. C-Albite core measurement: 10, 36.5, close to An70%, but measurement unreliable. Most other crystals too altered.

Groundmass feldspar laths are sometimes albite twinned, but often altered, especially cores. About 60%. RI on several grains gives fast below medium, Slow moderately above, so probably Sodic oligoclase rather than albite. Maybe 3–5% interstitial kspar but hard to tell.

Hornblende is green brown, anhedral, 3–5%, often partly uralitised and some is altered to chlorite. Max size 2mm, but also occurs as fine granular crystals in groundmass. Some have sector twinning and clusters of opaque Magnetite 3-4%. Trace epidote and apatite.

Quartz is sparse, maybe 5 or 10% in groundmass, as anyhedral crystals interstitial to feldspar and mafics, but sometimes occurs as patches and lenses of quartz mosaic with hornblende, maybe as a result of lit par lit iujection from the granitoid or a similar exchange of material.

Field Number		Formation:					
CF41C		Cerro Farellón Granitoid					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
273233	4882541		20	10	60	0	90
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
		5		4			
Other components:		Others:	Total:				
Epidote/apatite		1	100				
Final Rockname							
Porphyritic hypabyssal Hypersolvus micro-quartz monzodiorite.							

Microscopic textures (CF41C): Coarsely porphyritic Granitic rock with large, subhedral to euhedral plagioclase phenocrysts dominating the rock, with interstitial green hornblendes and granophyric quartz-kspar intergrowth.

Plagioclase is mostly large, euhedral to subhedral crystals with some zoning and mild sericitic alteration. About 55–60%, with crystals up to 5mm, sometimes glomeroporphyritic. Carlsbad-Albite on unzoned crystal gives: 10, 24, about An 45. Smaller crystals are slightly more sodic. Zoning appears to be oscillatory in the larger phenocrysts, usually within the andesine compositional range. Alteration of plagioclase is either veinlike cracking and saussurite with epidote and albitisation or some sericite alteration of calcic zones. Some crystals appear to be rimmed with K-spar.

Quartz occurs in anhedral 0.1 to 1mm, blobby to augular granophyric intergrowth with K-feldspar, interstitial to plagioclase, but occasionally nucleated on corners or edges of Plagioclase crystals. About 15–20%

K feldspar occurs as granophyric intergrowth with quartz, but also as anhedral to subhedral grains interstitial to plagioclase and mafics, sometimes invading fractured plagioclase crystals, and perhaps as rims on plagioclase crystals. 10%

Mafic mineral is green to green brown hornblende, 5% subhedral to anhedral, and often chloritised or uralitised, associated with clots of chlorite and trace apatite and epidote, plus 3–4%magnetite.

Field Number		Formation:					
CF24 *		Cerro Farellón Granitoid					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
272431	4876892		25	8	60	0	93
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
				2		3	
Other components:		Others:	Total:				
Epidote/titanite		2	100				
Final Rockname							
I type porphyritic biotite micro-granodiorite							

Microscopic textures (CF24): Porphyritic rock with euhedral to subhedral zoned magmatic plagioclase and some euhedral to skeletal or rimmed quartz, in a matrix of granular anhedral-subhedral quartz and chloritised biotite. Although this is still a granitic looking rock in mineralogy, the matrix is looking increasingly hypabyssal in texture.

Plagioclase is euhedral aud subhedral crystals up to 5mm, ranging down to 0.2mm or less, but mode about 1mm. About 55–60%. Some Glomeroporphyritic and some synueusis twinning? Almost all are zoned, usually oscillatory zoning, repeated calcic-sodic, but uot by much. ML not reliable. Sect T a on 2 unzoned to slightly zoned smaller crystal gives: 22.5, 25, about An 42% to 45%. Crystals with both inner and outer zones giving this % were seen, with lesser angles for intermediate zones, so oscillatory zoning appears to be between low andesine and calcic oligoclase. Some crystal rims have overgrown small groundmass quartz and kspar.

K-spar is difficult to spot, but may occur in the granular groundmass with quartz, and as intergrowth around rims of some large quartz. Groundmass k-spar is anhedral low RI crystals with moderate biaxial 2v, perhaps Orthoclase. Some plagioclase crystals had outer rims through which plagioclase twin planes do not pass, possibly a thin K-spar rim. 5–8%

Quartz occurs in two populations, 0.5mm-1mm subhedral partly skeletal or irregularly rimmed crystals as phenocrysts, and more anhedral sub 0.1mm granular mosaic crystals interstital to plagioclase and larger quartz. Larger crystals are sometimes skeletal or granophyric at rims. About 20–25%

Biotite is about 3%, 1mm or less, subhedral to anhedral cleavage flakes and basal sections, interstitial to larger populations , and often chloritised. Forms clusters with opaques, titanite and epidote, and occurs sometimes as inclusions within sieve textured or irregular feldspar. Epidote: bright yellow-green, trace, occurs with biotite. Also titanite, trace, ocurs with biotite and epidote. Opaques 1–2%, altered to leucoxene.

Field Number	Formation:					
CF1B	Cerro Farell6u Granitoid					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
275283	4876600					0
Final Rockname						
Altered hypabyssal dacite-rhyodacite.						

Microscopic textures (CF1B): Very similar rock to CF 1, with the same textures, slightly more feldspars and larger crystals, but altered in the same way.

Altered porphyritic rock, with sericitised plag, chloritised mafics and rounded, embayed beta quartz as phenocrysts in a granular groundmass of quartz/feldspar microphenocrysts and chlorite, sericite, calcite, with trace apatite. ?Muscovite occurs as a replacement of ?biotite?, but appears almost uniaxial negative — Very low 2v Phengite?

Large plagioclase phenocrysts are up to 4mm, euhedral to subhedral, often glomeroporphyritic. Most crystals are sericitised and possibly albitised, but show evidence of oscillatory zoning in the Andesine to Oligoclase area. Some crystals also patchily replaced with calcite, and may have been auti-perthitic.

Mafics are eutirely replaced by opaques, green chlorite, leucoxene and sometimes unusually low 2v muscovite (almost pseudo-uniaxial), clay and calcite. From blocky or elongate shapes, probably pseudomorphs of hornblende, although some may have been biotite.

Quartz is sparse, large phenocrysts, up to 3-4mm, rounded and embayed beta quartz. Also some crystals present as part of groundmass mosaic/grauular material, may be secoudary.

Groundmass is quartz/altered feldspar, chloritised mafics, occasional apatite, euhedral., secondary calcite

Altered hypabyssal dacite-rhyodacite.

Field Number	Formation:					
CF1	Cerro Farellón Granitoid					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
275283	4876600					0
Final Rockname						
Altered hypabyssal dacite-rhyodacite. No chem.						

Microscopic textures (CF1): Altered porphyritic rock, with sericitised plag, chloritised mafics and rounded, embayed beta quartz as phenocrysts in a granular groundmass of quartz/feldspar microphenocrysts and chlorite, sericite, calcite, with trace apatite.

Large plagioclase phenocrysts are up to 4mm, euhedral to subhedral, often glomeroporphyritic. Most crystals are sericitised and possibly albitised, but show evidence of oscillatory zoning in the Andesine to Oligoclase area. Some crystals also patchily replaced with calcite, and may have been anti-perthitic.

Mafics are entirely replaced by opaques, green chlorite, leucoxene and sometimes muscovite, clay and calcite. From blocky or elongate shapes, probably pseudomorphs of hornblende, although some may have been biotite.

Quartz is sparse, large phenocrysts, up to 3–4mm, rounded and embayed beta quartz. Also some crystals present as part of groundmass mosaic/granular material, may be secondary.

Groundmass is quartz/altered feldspar, chloritised mafics, occasional apatite, euhedral., secondary calcite

Altered hypabyssal dacite-rhyodacite.

Field Number	Formation:					
CF2	Cerro Farell6u Granitoid					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
274995	4877100					0
Final Rockname						
Hydrothermally altered hypabyssal dacitoid.						

Microscopic textures (CF2): Porphyritic hypabyssal textured rock, with phenocrysts of Plagioclase in a granular groundmass, very highly altered. Almost all plagioclase is euhedral to subhedral crystals, replaced entirely by calcite and sericite. Groundmass is patches of calcite, sericitised feldspar, recrystallised quartz. Mafics are altered by chlorite and calcite.

Field Number		Formation:					
CF12C		Cerro Farellón Granitoid?					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
273306	4876512		10	10	60	0	80
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
			12	5			
Other components:		Others:	Total:				
Epidote/calcite/etc		3	100				
Final Rockname							
Hornfelsed or propylitised hypabyssal or quartz micro-monzodiorite, maybe quartz micro-diorite.							

Microscopic textures (CF12C): Very altered rock, porphyritic with a microgranular altered groundmass. Could be called either a microgranitoid or hypabyssal.

Rock has 60% phenocrysts of saussauritised euhedral/subhedral 1–5mm sodic plagioclase and chloritised mafics in a groundmass of microgranular altered plagioclase and mafics with a lot of secondary calcite and epidote. Altered magnenite as opaque.

K-spar hard to spot if it is there, estimate 5–10% in groundmass.

Groundmass is chaotic felsitic material, saussuritised small plag, 5–10% minor granular or partly mosaic quartz, secondary epidote and calcite, plus 10–12% or so chlorite after mafics.

Rounded Cognate? Xenolith of partly saussuritised large plagioclase in matrix of microgranular and partly pilotaxitic feldspar and altered mafics may be associated with the blocks and boulders of exotic material within the intrusion, as described in the field.

Field Number	Formation:					
CF12B	Cerro Farellón Granitoid?					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
273306	4876512					0
Final Rockname						
Hornfelsed or propylitised dacitoid subvolcanic intrusive probably associated with Cerro Farellón complex.						

Microscopic textures (CF12B): Altered porphyritic rock with pseudomorphs of feldspar and mafic minerals set in a matrix of very fine grained felsitic material.

Feldspars were up to 5mm, euhedral, rounded, some glomeroporphyritic, but are now altered to saussurite, with pseudomorphs of sericite, yellow green epidote and calcite replacing most of the original crystals.

Mafic phase, probably hornblende, is now pseudomorphed by pleochroic green chlorite and granular epidote, plus some leucoxene. Chlorite is anomalous blue in cpl, and is quite strongly green — iron rich.

Matrix is slightly recrystallised fine grained felsitic material.

Field Number	Formation:					
LH1	Cerro Pirámide Granitoid					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
279060	4876560					0
Final Rockname						
Hydrothermally altered hypabyssal micro-quartz diorite						

Microscopic textures (LH1): Altered porphryritic rock with phenocrysts of plagioclase and green amphibole in a murky, microgranular groundmass of altered feldspar, quartz, chlorite, misc. alteration products and opaques. Amphiboles are altered to chlorite, and have distinct reaction rims with overgrown opaques. Plagioclase is sericitised, and both epidote and prehnite occur as alteration associated with altered plag. Quartz occurs in groundmass as both primary mineral and secondary alteration product in cavities.

Hydrothermally altered hypabyssal quartz dioritioid.

Field Number		Formation:					
CP62 *		Cerro Pirámide Granitoid					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
274264	4873586		23	9	58	0	90
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
			5	3			
Other components:		Others:	Total:				
epidote, calcite etc		2	100				
Final Rockname							
Porphyritic Hornblende Microgranodiorite							

Microscopic textures (CP62): Very similar rock in texture to CP61, a porphryritic microgranitoid with phenocrysts of plagioclase, hornblende and quartz in a groundmass of granular quartz and feldspar. However, this rock is very much more altered than CP61, with saussuritised plagioclase and chloritised mafics.

Plagioclase phenocrysts are about 25%, subhedral and euhedral, up to 5mm, avg about 2mm. Phenocrysts are often partly sericitised, and some are saussnritised, replaced with albite and fine grained sericite and granular yellow-green epidote..

Quartz phenocrysts (1–2%, 0.5–3mm) are rounded subhedral bipyramids, with an overgrown rim of granular groundmass quartz, sometimes granophyric with k-spar.

Mafic phases are about 5% euhdral and subhedral 0.5–1.5mm pseudomorphs of amphibole in green pleochroic chlorite and epidote.

Groundmass is fine grained granular mosaic of quartz and feldspar with about 2–3% opaques, patches of chlorite and epidote after hornblende, and traces of apatite.

Granular groundmass difficult to estimate for QAPF. Normative composition is: Q23, A9, P58.

Field Number		Formation:					
PI89 *		Cerro Pirámide Granitoid					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
277085	4872918		20	10	60	0	90
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
			5	4			
Other components:		Others:	Total:				
Epidote, calcite, etc		1	100				
Final Rockname							
Porophyritic hornblende microgranodiorite.							

Microscopic textures (PI89): Porphryritic microgranitoid very similar to CP61, CP62. Dominant phenocryst phase is euhedral to subhedral zoned and sieve textured plagioclase, with chloritised hornblendes and occasional rounded quartz bipyramids.

Plagioclase is about 30%, 1–6mm, euhedral and subhedral crystals with oscillatory zoning sieve textures and common alteration, with patchy or vein replacement by K-spar and common sericitisation and partial saussuritisation in some crystals with epidote occuring within phenocrysts along with sericite. Also some patchy replacement by calcite. By RI Fast is below epoxy and slow just above, so about An10%, albite or albitised by alteration. Carlsbad-Albite twinned and zoned crystals give from 32,9 to 13,6 at rim, about An60 to An30%, Labradorite to Oligoclase. So, phenocrysts are zoned Labradorite to Oligoclase, and are partially albitised with development of sericite and epidote.

Amphiboles (and any biotite) are pseudomorphed by chlorite, with occasional 60–120 cleavage lozenges visible in pseudomorphed end sections. Chlorite is dark green pleochroic with purple-blue interference colours, also some leucoxene, other opaques and calcite occur in amphibole pseudomorphs. Originally about 5%, up to 3mm.

Quartz phenocrysts are sparse, rounded bipyramids, 5%, up to 1mm, with some overgrowth of granular quartz from groundmass. Occasional twinned crystals.

Groundmass is about 65% of rock, fine grained and granular, with % minerals difficult to identify, about 15% granular anhedral quartz, remainder 3-4% opaques and approx 30% partially sericitised plagioclase and maybe 5-10 % anhedral k-spar, but difficult to determine except where it is replacing parts of larger Plag phenocrysts.

Field Number		Formation:					
GA15A *		Cerro Pirámide Granitoid					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
280040	4875980		20	5	60	0	85
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
		8		5		1	
Other components:		Others:	Total:				
apatite, zircon, sericite		1	100				
Final Rockname							
Hornblende microgranodiorite							

Microscopic textures (GA15A): Porphyritic plagiophyric microgranitoid with phenocrysts of plagioclase in a medium grained microgranular quartz-feldspar groundmass. Similar textures to several of the other Cerro Pirámide Intrusive samples, all of which vary between micrograníitic and hypabyssal volcanic textures.

Plagioclase is the dominant phenocryst, about 25% of the rock, with .3–4mm euhedral and subhedral crystals, sometimes oscillatory zoned (zoning is static or normal oscillatory.) or glomeroporphyritic, slightly sericitised. Section perp a gives: 25, about An 36%, Andesine.

Main Mafic phase is subhedral sparse (5–6%) small Phenocrysts of hornblende, pale colourless to brown pleocrhroic mineral, faint. Sometimes occurs as patches or clusters of fine grained material in groundmass, altered, or as subhedral prismatic crystals.

Groundmass is microgranular textured, about 30–35% euhedral/subhedral plag microphenocryss with interstitial granitic textured anhedral quartz (15–20%) and maybe trace to 5% K-spar, together with 2% fine grained amphibole, 5% opaque magnetite, trace biotite, chlorite alteration, sericite and opaques. Groundmass plagioclase ML: 12.5, 10.5, 10, 9, etc, An 5% or 20%, and C-Albite gives:2, 12, also about An20-25%, Oligoclase. Groundmass K-spar is anhedral, low releif, difficult to spot except for releif differences.

Field Number		Formation:					
CP52		Cerro Pirámide Granitoid					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
275385	4871444		21	6	63	0	90
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
			5	2			
Other components:		Others:	Total:				
epidote, calcite, sericite		3	100				
Final Rockname							
Granodiorite.							

Microscopic textures (CP52): Strongly altered porphyritic rock with phenocrysts of saussuritised plagioclase and chloritised hornblende in a granular recrystallised quartz-mosaic groundmass.

Phenocryst plagioclase are altered, either sericitised/Saussauritised or replaced by calcite. Otherwise were euhedral to subhedral large crystals, 1–6mm, glomeroporphyritic, remnant ML gives: 13, 19, 16, 11, 15, 20, 10, Max 20 gives either An% 0 or 20, while Rl of both fast and slow directions is well below epoxy, so probably Albite or albitised due to saussuritisation. About 35–40%

Mafics altered to Chlorite or occasionally chlorite/epidote, euhedral to subhedral 0.5–2mm pseudomorphs of hornblende, about 5%. Some have reaction rims of opaque minerals.

Phenocryst quartz is about 3–5%, small sub 1mm rounded or corroded crystals.

Groundmass is murky, rexxlised to granular quartz/feldspar mosaic, some small albite phenocrysts, with 1–2% oxidised opaques and patches of sericite, chlorite, epidote and occasional calcite, too fine and altered for mineral estimation. Occasional small drusy cavities with euhedral quartz lining and chlorite infill.

QAPF extrapolated from norm: Q21, A6, P63.

Field Number CP60		Formation: Cerro Pirámide Granitoid					
Utm East 277090	Utm North 4872000		Q: 10	A: 15	P: 62	F: 0	Subtotal: 87
Cpx:	Opx:	Amph: 7	Chlorite:	Opaques: 4	Muscovite:	Biotite: 1	Olivine:
Other components: epidote/sphene/zircon/apatite		Others: 1	Total: 100				
Final Rockname QAPF gives Quartz Monzodiorite, while TAS gives Syeno-diorite.							

Microscopic textures (CP60): Moderately altered microgranitoid, with main phase of plagioclase, often euhedral and zoned, with interstitial hornblende, chloritised biotite, granophyric quartz/k-spar intergrowth and minor phases of magnetite, sphene, secondary chlorite and void filling calcite.

Plagioclase is euhedral to subhedral crystals, often with oscillatory zoning, and common partial sericitic alteration to cores. Some crystals also invaded by veinlike secondary K-spar replacement. Crystals are up to 2mm when large and euhedral and groundmass crystals are blocky subhedral crystals about 0.5 to 1mm. Albite-carlsbad on cores gives: 12,29, about An55%, while outer rims of large crystals are zoned down to albite and are overgrown by k-spar rims and patches of quartz/k-spar granophyric intergrowth. About 60-65% of rock.

Quartz occurs as anhedral interstitial grains, generally 0.5mm or less, often in granophyric intergrowth with k-spar. 10%.

K-spar is sparse, either as interstitial material in intergrowth with quartz or as rims on plagioclase. About 10–15%, sub 1mm. Also as secondary fracture/cleavage invasion replacement of plagioclase.

Biotite is about 1% pleochroic straw to red brown biotite, up to 2mm, generally chloritised to grass green or purple pleochroic chlorite in cpl.

Hornblende is more common, about, 5–8%, partially chloritised or uralitised, subhedral and interstitial to the plagioclase, up to 2mm, or 5mm, green-brown or light to dark green pleochroic.

Opaques are common blocky magnetite, about 4–5%, with traces ofsphene, secondary epidote, void filling calcite, also minor apatite and zircon.

Field Number CP61		Formation: Cerro Pirámide Granitoid					
Utm East 276620	Utm North 4871950		Q: 25	A: 5	P: 60	F: 0	Subtotal: 90
Cpx:	Opx:	Amph: 3	Chlorite: 2	Opaques: 4	Muscovite:	Biotite:	Olivine:
Other components: zircon/apatite		Others: 1	Total: 100				
Final Rockname Porphyritic Hornblende Microgranodiorite.							

Microscopic textures (CP61): Porphryitic rock with phenocryst phase of 1–5mm subhedral to euhedral zoned and sieve textured plagioclase, 1–2mm altered and reaction rimmed green-brown amphiboles and occasional rounded quartz phenocrysts, in a fine graned granular matrix of subhedral feldspar and anhedral quartz.

Plagioclase phenocrysts are about 20%, up to 5mm, avg 2mm or less. Crystals are zoned, glomeroporphyritic, partly sericitised and seamed with fine fractures. Zoned crystal with section perp a gives cores of An50% down to oligoclase or albite at rims, while Albite-Carlsbad twins give 11, 21, about An40%, so plagioclase crystals are oscillatory normally zoned crystals from sodic Labradorite through to Oligoclase, with some albite on rims. Most phenocrysts have minor sericite, and occasional epidote alteration also occurs.

Quartz phenocrysts are rare, about 5% or less, rounded subhedral or skeletal bipyramids, with slight rimming or framework overgrowth with optically continuous groundmass quartz. Up to 2–3mm.

Hornblende is green to brown pleochroic subhedral crystals with opaques and leucoxene as alteration, also sometimes nralitised or replaced by platy chlorite. Some crystals are rounded with reaction rims. About 3%

Groundmass is about 75% of rock, with about 20% fine granular anhedral quartz, 2–3% chloritised mafics, 3–4% magnetite, up to 0.5mm. 1% trace minerals such as zircon and apatite, also minor secondary epidote, but is mostly 40% murky subhedral plagioclase, RI greater than epoxy, but with some (5% or less) k-spar in intergrowth with quartzrimmed phenocrysts.

Field Number		Formation:					
GPS081		Cerro Pirámide Granitoid					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
278244	4872248		22	12	55	0	89
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
			5	4			
Other components:		Others:	Total:				
epidote/calcite altn.		2	100				
Final Rockname							
Porphyritic hornblende microgranodiorite.							

Microscopic textures (GPS081): Porphyritic rock with phenocrysts of Quartz, Plagioclase and an altered mafic, in a matrix of granular or isogranular fine quartz and feldspar.

Plagioclase phenocrysts are about 15–20% of the rock, .5–5mm. Crystals are euhedral, sometimes rounded or glomeroporphyritic. Crystals are quite altered, such that twinning methods for identification are useless. Saussuritisation has occurred, leaving crystals studded with epidote, sericite and calcite patches, and seamed with cracks. RI of remnant feldspar within the crystals has both fast and slow distinctly below medium, so probably albitised.

Quartz phenocrysts are rounded bipyramidal beta quartz pseudomorphs, about 2%, np to 1.5mm, with slightly fuzzy edges where groundmass crystals have nucleated on the phenocryst and given it a corona or halo of fine grains around it in optical continuity with the parent grain.

Mafic phenocrysts are 5% blocky or elongate pseudomorphs of green chlorite with dark grey to blue grey interfence colours. Chlorite is sometimes chaotic, but sometimes platy and aligned along the long axis of the older mineral. Looks like chlorite replacing amphiboles.

Groundmass is fine grained granular quartz and altered sodic plagioclase, together with some anhedral ?K-spar, low RI groundmass material. Also fine grained disseminated chlorite and occasional epidote. About 25% quartz, Say 35% plagioclase and 10-12% K-spar, 3-4% fine granular magnetite.

Field Number		Formation:					
BERT1 *		Lago Bertrand Granitoid					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
660670	4792090		30	15	50	0	95
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
		1		2		2	
Other components:		Others:	Total:				
epidote, zircon, apatite			100				
Final Rockname							
Biotite granite, I type.							

Microscopic textures (BERT1):

Bert 2 (Bert 1 was too altered for dating, so will not be reviewed here.)

Rock is a fairly altered granitoid, with plagioclase sericitised, some hornblendes uralitised or chloritised. Biotite, if present, has been altered to chlorite. Epidote common as alteration of ?biotite and hornblende. Texture is granitic, but with euhedral plagioclase, sericitised, in poikilitic texture within large grains of quartz and K-spar. Amphiboles are bright green pleochroic hornblende, sometimes cloritised/uralitised, associated with chloritised biotite pseudomorphs.

Plagioclase is poikilitically enclosed by qnartz or k feldspar, with subhedral and euhedral grains up to 3mm, about 45–50%. Zoning is common, oscillatory and normal, but with most grains only rims remain, as sericitisation has altered all cores, bar some smaller grains within quartz. ML on remnant crystal rims and smaller plagioclase within qnartz: 18, 9.5, 29.5, 28, 30, 24.5, 17.5, about An54%, Sodic Labradorite. Cores were probably more calcic.

K-spar is very finely perthitic, low RI grains, anhedral, about 1–3mm, perhaps 15–20%. Grains are poikilitic about some plagioclase, and when perthite is well developed small albite twins are visible.

Quartz is about 30%, large.5–2mm, anhedral grains, poikilitically enclosing plagioclase, and some times chloritised hornblende or biotite.

Hornblende is bright green pleochroic, subhedral large crystals up to 6mm, occasionally zoned. Some grains altered with chlorite or uralite around edges, but generally unaltered. 1%.

Biotite occurs only as chlorite or chlorite/epidote pseudomorphs of euhedral booklets. Chlorite retains same crystallographic orientation. Up to 1mm, about 1–2%. Chlorite is unusually bright green, and some have epidote as alteration also. 1–2% magnetite opaque, usually with biotite/hornblende clusters. Trace yellow green epidote as primary interstitial mineral.

Accessory minerals include: titanite, apatite, trace zircon. Opaque is small and blocky, so most likely magnetite.

Field Number		Formation:					
Esmeralda *		Lago Esmeralda Granitoid					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
228533	4750175		25	15	47	0	87
Opx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
		5		5		2	
Other components:		Others:	Total:				
Apatite, zircon etc.		1	100				
Final Rockname							
Partly altered/sericitised Hornblende Granodiorite, I type.							

Microscopic textures (Esmeralda):

Medium to coarse grained granitoid with euhedral sericitised plagioclase, green hornblende, quartz in graphic intergrowth with k-feldspar, minor biotite.

Plagioclase is euhedral to subhedral crystals 0.5–3mm, about 45–50% sometimes glomeroporphyritic. Crystals are zoned, normal or oscillatory normal, with most crystals having sericitised cores, or more calcic zones. Some crystals appear to have low RI K-spar rim. ML on remnant plagioclase: 26.5, 27, 29.5, 21.5, 22.5, 19.5, 12.5, about An52%, Sodic Labradorite, although these remnants are mostly rim areas, so cores were probably more calcic before alteration.

Quartz occurs either as large anhedral crystals interstitial to the plagioclase, up to 4mm, or as cellular angular grains in ?graphic intergrowth with k-feldspar. Graphically intergrown material often is nucleated on larger grains without intergrowth. About 25–30%.

K-feldspar occurs as occasional subhedral crystals up to 1mm, but generally as anhedral cellular crystals in graphic intergrowth with quartz. About 10–15%.

Hornblende is subhedral green pleochroic crystals, 0.5–2mm, often uralitised and fibrous, but enough unaltered crystals to date (see notes.) About 3–5%.

Biotite is small, sub 1mm grains, altered to bright green pleochroic chlorite. About 2–3%.

Field Number		Formation:					
PI62 *		Puerto Ibáñez Granitoid					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
273300	4872725		20	10	55	0	85
Opx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
		6		5			
Other components:		Others:	Total:				
epidote, sphene, apatite		4	100				
Final Rockname							
Porphyritic hornblende microgranodiorite.							

Microscopic textures (PI62):

Porphyritic microgranitoid, with about 40% phenocryst content. Dominant phenocryst is plagioclase, followed by green-brown hornblende then quartz. Some sericite, chlorite and uralite as alteration products.

Plagioclase is about 30%, 1–5mm crystals, euhedral to subhedral, sometimes sieve textured, zoned and glomeroporphyritic. Some phenocrysts are sericitised, particularly on outer rims, and some saussiritised crystals occur with epidote in the altered rims. Zoned crystals have normal oscillatory zoning. M-L on the cores of less altered phenocrysts is: 25, 31.5, 23, 30, 20, 23.5, 32, so about An 55%, Labradorite.

Quartz phenocrysts are rounded and subhedral bipyramids, often skeletal and embayed, about 5%, up to 4mm. Rims are overgrown with optically continuous fine granular or partially granophyric quartz with low RI k-spar intergrowth.

Hornblendes are green to green brown pleochroic, subhedral to anhedral elongate crystals, about 5–6%, up to 5mm. Often associated with magnetite, and rimmed with reaction rim including fine grained magnetite or similar opaques. Some crystals replaced by fibrous green uralite and chlorite, and ocasional patchy calcite.

Trace biotite, as inclusion within hornblende.

Opaques are blocky magnetite, about 3–5%.

Groundmass is about 55% of rock, quite equigranular with 10–15% subhedral or anhedral quartz, 5–10% mafics and opaques, 20–25% fine grained subhedral sodic plagioclase and maybe 5–10% low RI anhedral k-spar.

Field Number	Formation:					
PI75A *	Puerto Ibáñez Granitoid					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
274350	4873950					0
Final Rockname						
Weathered microgranodiorite.						

Microscopic textures (PI75A):

Probably hypabyssal quartz microdiorite or diorite. Granitic textured rock with large subhedral altered plagioclase (40%), mostly gone to calcite/sericite. Quartz (5-10%) occurs as subhedral to rounded phenocrysts, also anhedral recrystallised material in g/mass and as drusy lining of cavities with calcite. Groundmass is murky grey to brown altered and mosaic recrystallised material with secondary calcite replacment common, and patches of sericite. Any mafics and opaques altered to hematite and Leucoxene. Trace chlorite after mafic minerals, 2–3%.

Too altered for QAPF, and chemistry has high LOI, probably due to prevalent calcite.

Field Number		Formation:					
PI23 *		Puerto Ibáñez Granitoid					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
274440	4871950		19	10	55	0	84
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
		8	1	5			
Other components:		Others:	Total:				
sphene, epidote, calcite, sericite.		2	100				
Final Rockname							
Microgranular porphyritic hornblende microgranodiorite. I type.							

Microscopic textures (PI23):

Strongly porphyritic rock with Boundary line hypabyssal textures. Could be either volcanic or Plutonic. Euhedral plagioclase and subhedral green hornblende and rounded beta quartz phenocrysts occur in a matrix of equigranular quartz and feldspar. Alteration products include sericite, epidote, uralite and chlorite.

Plagioclase is the dominant phenocryst phase, about 40%, occuring as large 1–6mm, euhedral crystals with cracking and sericitisation of rims. Zoning is rare either normal or oscillatory normal. Twins are albite-carlsbad. C-A on large plagioclase cores: 32.5, 11.5, About An60%, also 18.5, 32, About An 58%, both on LT curve. Labradorite.

Groundmass plagioclase is sub1mm population and 0.1–0.5mm groundmass crystals, are murky, cracked, altered to sericite and sometimes epidote, indicating some saussuritisation. 10–15%.

Quartz is present both as phenocrysts and in the groundmass. Phenocryst quartz is 0.5–3mm, rounded and embayed pseudomorphs of beta quartz, about 3%. Groundmass quartz is fine grained, anhedral, interstitial to and equigranular with murky, altered groundmass feldspar, about .05mm. About 15–16%. Phenocryst bipyramids have been overgrown with optically continous fine grains of groundmass quartz.

Other major groundmass mineral is murky, anhedral low RI material, RI well below quartz, probably K-Feldspar. Difficult to identify, but perhaps up to 10 % of rock.

Amphibole is subhedral to euhedral green pleochroic hornblende, often with reaction rims and opaques. Alters to fibrous green uralite or green chlorite, and occasionally epidote. O.5–5mm, 8–10%.

Alteration products are chlorite as void filling and with uralite altering amphiboles, sericite, clay and epidote altering feldspars. Opaques are magnetite, about 5%.

Field Number		Formation:					
CP78		South Cerro Pirámide Diorite					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
279442	4869264		15	0	70	0	85
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
		10	3	2			
Other components:		Others:	Total:				
			100				
Final Rockname							
Altered hornblende quartz microdiorite. I type.							

Microscopic textures (CP78):

Similar, although more altered and slightly coarser grained, to CP77, an equigranular rock dominated by plagioclase, with interstitial quartz, green hornblende and brown biotite, with more extensive chlorite alteration and magnetite opaque.

Plagioclase is euhedral to subhedral, 0.4-5mm, 70%. More pervasive cracking and sericitisation than CP77, but still texure is raudomly aligned framework texture with interstitial quartz and mafics. Some crystals zoned, both normal and oscillatory normal. Sieve textures occur, but rarely. Sericitisation is more advanced, although it does not seem to be confined to calcic zones of crystals, rather being more uniform.

Quartz is larger than '77, as anhedral grains up to 2mm, sometimes subhedral or slightly granophyric, interstitial to the plagioclase. About 10–15%.

Mafic phases are chloritised or uralitised green hornblende, about .2–2mm, anhedral, sometimes chloritised, about 10%, and relic brown biotite, almost all chloritised, about 3-5%. Opaque is magnetite, also pyrite, about 2-3%. Accesssories include apatite, maybe titanite, trace zircon.

Alteration is sericitisation of plagioclase and chloritisation of most biotite and hornblende. Calcite also occurs. Also trace epidote.

Field Number		Formation:					
CP83 *		South Cerro Pirámide Diorite					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
278860	4869480		12	10	60	0	82
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
		8		8			
Other components:		Others:	Total:				
apatie, sphene, epidote		2	100				
Final Rockname							
Hornblende microgranodiorite or hornblende quartz micro-monzodiorite, depending on quartz estimation.							

Microscopic textures (CP83):

Granitoid or microgranitoid, Plagiophyric, with large subhedral granitic textured plagioclase with anhedral interstitial quartz/amphibole/trace minerals.

Plagioclase is about 55–60%, large (up to 3mm) subhedral to euhedral crystals, often zoned, sometimes with sericitic alteration and some saussauritisation in occasional crystals. Zoning is normal oscillatory, example ML gives 16 to 45 degrees, with a major jump between core and rim from calcic oligoclase by RI at rim, to core of Labradorite to Bytownite by ML. Smaller crystals without strong zoning give C-Albite of 8, 20, and 7, 25, An% 38–47 respectively, Andesine. Outer rims around some plagioclase have RI well below fast quartz and albite twins do not continue through this rim, if it is present, therefore probably Orthoclase rim as late overgrowth.

Orthoclase also occurs as very low RI anhedral or occasional subhedral crystals, occasionally carlsbad twinned, interstitial to plagioclase and very occasionally in very poor granophyric intergrowth with quartz. 2v high, 80 ish, oap T 010. Max 0.4mm, maybe 5–10% max.

Quartz is anhedral grains, interstitial to plagioclase and large amphibole, perhaps 10–12%, occasionally in poor granophyric intergrowth with Orthoclase.

Amphibiole is pleochroic green or green brown, subhedral or anhedral, often altered to fibrous green uralite, or to green/brown platy chlorite. 2–3mm max, about 5–8%.

Trace minerals include 5–8% magnetite, trace Epidote, both primary and as alteration and component of saussuritised plagioclase. Also present is apatite, sphene, minor epidote and alteration products include sericite and saussurite in plagioclase, uralite and chlorite in amphibole.

Field Number		Formation:					
CP77 *		South Cerro Pirámide Diorite					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
279163	4869108		8	5	65	0	78
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
		10		7		3	
Other components:		Others:	Total:				
sphene, apatite, etc		2	100				
Final Rockname							
Biotite-hornblende micro-quartz diorite. I type.							

Microscopic textures (CP77):

Equigranular rock dominated by plagioclase, with interstitial quartz, green hornblende and brown biotite, with some chlorite alteration and magnetite opaque.

Plagioclase is euhedral to subhedral, 0.4mm–2mm, 60–65%. Some coarse flow orientation, but generally randomly aligned framework texture with interstitial quartz and mafics. Some crystals zoned, both normal and oscillatory normal. Sieve textures occur, but rarely. Alteration is mainly mild sericitisation. ML on Cores: 29.5, 20.5, 27.5, 30, 35, 31, 31.5, About An 61%, Labradorite, ranging down to calcic andesine at the rims, although some small later stage crystals have rims through which albite twins do not pass, perhaps k-spar rim, trace to 5%. C-A reading on plagioclase gives: 31, 15, about An 57%.

Quartz is present as small, sub 0.2mm anhedral grains interstitial to the plagioclase. About 5–8%.

Mafic phases are partly uralitised green hornblende, about 0.2–0.6mm, anhedral, sometimes chloritised, about 10%, and brown biotite, chloritised, about 3%. Opaque is magnetite, also about 5–8%. Accesssories include apatite, maybe titanite.

Alteration is sericitisation of plagioclase, also uralitisation of hornblende and chloritisation of some biotite and hornblende. Calcite also occurs.

Field Number		Formation:					
WI95C *		West Ibáñez Granitoid					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
272830	4864080		17	5	60	0	82
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
		3		5		5	
Other components:		Others:	Total:				
trace min/voidfilling		5	100				
Final Rockname							
I type biotite microgranodiorite.							

Microscopic textures (WI95C):

Granitic rock with euhedral-subhedral plagioclase, almost cumulate in texture, with interstitial quartz, altered biotite and secondary chlorite, sericite and calcite. Quartz looks a bit granophyric, but not much.

Feldspars are euhedral to subhedral 0.5–4mm plagioclase, often zoned, and apparently with outer rim of k-spar, probably orthoclase. Albite-carlsbad gives: 9, 27.5, about An53%, Sodic Labradorite, but outer zones appear to range down to albite, and some crystals have outermost rim through which albite twin planes do not pass, and RI is strongly below quartz and inner plagioclase layers, so probably orthoclase k-spar. Estimate about 60% Plagioclase, sub 5% K-spar. Sericitisation is common in plagioclase.

Quartz is anhedral, granitic quartz with slight undulatory extinction. Occurs as 0.5–2mm interstitial crystals to euhedral plagioclase, and is very slightly granophyric with k-spar at some points. About 15–17%.

Remaining portion of rock is interstitial 0.1–3mm minerals, about 5% biotite, some chloritised, 2–3% brown hornblende, and 5% opaques, along with traces of apatite, zircon and with sericite and calcite as void filling.

Field Number	Formation:					
WI95D	West Ibáñez Granitoid					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
272830	4864080					0
Final Rockname						
Quenched near contact version of WI95 microgranodioritoid. Unusually low plagioclase content, high silica.						

Microscopic textures (WI95D):

Porphyritic micro-granitoid, with large (up to 4mm) euhedral plagioclase, in a complex poikilomosaic groundmass of quartz, fine plagioclase, trace k-spar, magnetite, biotite, secondary sericitic muscovite and chlorite.

This rock has significantly different textures, although similar mineralogy, to the other WI95 granitoid samples. It may be part of a chilled or quenched marginal facies, part of the roof or side contacts of the intrusion.

Large feldspar phenocrysts are euhedral or subhedral plagioclase, 1–4mm, sometimes glomeroporphyritic, often with incipient or patchy sericitisation, albite, carlsbad and cross-hatched twinned. Some K-spar crystals, but difficult to spot. By ML and RI, Plagioclase is Albite to sodic oligoclase.

Quartz is ubiquitous in the groundmass as anhedral complexly intergrown quartz mosaic with poikilomosaic texture including fine grained feldspar and biotite and opaques. Texture looks like a quench texture. Small groundmass feldspars are sodic plagioclase. If K-spar is present, it is as small, anhedral low releif, low RI crystals overgrown by the quartz, although some altered crystals show mosaic of low RI k-spar replacing ?

Biotite is brown, inclusters with opaques, maybe with traces of brown hornblende. Minor chloritisation.

Field Number	Formation:					
WI95E	West Ibáñez Granitoid					
Utm East	Utm North	Q:	A:	P:	F:	Subtotal:
272830	4864080					0
Final Rockname						
K-spar/Quartz Aplite vein in Hornblende-biotite microgranodiorite.						

Microscopic textures (WI95E):

Granitoid host is micro-granodioritoid, analogous to WI95 C, though with a little more hornblende and less biotite, but has 8mm wide fine grained aplitic vein cutting it along a smooth edged broken fracture.

Vein margins are very fine grained, with a chilled margin. Internal part of vein is subhedral to anhedral equigranular quartz, sodic plagioclase and murky k-feldspar, with very rare biotite/(chloritised.) Minor euhedral to subhedral magnetite opaques. Grainsize overall for most crystals is b/w 0.1 to 0.4mm, but finer at chilled margins.

K-feldspar and quartz are equigranular, but the quartz is often slightly myrmekitic, but not often. Both are generally anhedral to subhedral. K-feldspar is easily distinguishable from very low RI and a grey, murky clay alteration to most crystals.

This vein is a fairly classic aplite, characteristic of late stage dry melt characteristics.

Field Number		Formation:					
WI96A		West Ibáñez Granitoid					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
272580	4863880		10	5	70	0	85
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
		10		5			
Other components:		Others:	Total:				
			100				
Final Rockname							
Hypabyssal altered hornblende micro quartzdiorite to quartz monzodiorite. I type.							

Microscopic textures (WI96A):

Porphyritic microgranitoid, with altered phenocrysts of plagioclase and chloritised/uralitised green amphibole in an equigranular plag/quartz groundmass. Secondary alteration includes sericite, calcite, chlorite and epidote.

Plagioclase is mostly small 0.2–0.5mm groundmass crystals, subhedral, in hypidiomorphic texture with quartz and opaques. Murky and cracked with incipient sericitisation. Some larger phenocrysts up to 2mm, but sparse. ML on groundmass plagioclase, cores if possible: 10, 24, 23, 20.5, 16, 19, 32: About An55%, Labradorite. Crystals are normally zoned, and outer rims show very low extinction angles and fade out of twins, possibly indicating a (trace to 5%) K-spar rim on some crystals. What few large phenocrysts occur show similar composition, but have oscillatory normal zoning. About 65-70%. Alteration products include sericite, epidote and finegrained clays and calcite.

Quartz is fine, 0.2–0.3mm anhedral crystals in groundmass, generally interstitial to plagioclase. About 10%.

Mafic minerals, including the pleochroic green hornblende and its alteration products are about 10% Remnant amphiboles are green pleochroic subhedral crystals, some up to 4mm, sometimes fibrous and uralitised or surrounded by reaction rims of chlorite and opaques. Some have calcite alteration also associated with reaction rims.

Opaques are fine grained, square and blocky, about 5%.

Field Number		Formation:					
W147 *		West Ibáñez Granitoid					
Utm East	Utm North		CF/Q/Q:	RF/R/A:	Vit/F/ P:	F:	Subtotal:
273320	4858150		5	15	55	0	75
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
			10	10			
Other components:		Others:	Total:				
Epidote, clacite, sericite,		5	100				
Final Rockname							
QAPF gives monzodiorite, while chemistry is syenodiorite. Probably an altered granodiorite/diorite.							

Microscopic textures (WI47):

Altered microgranitic textured rock, with altered brown subhedral and euhedral plagioclase, large subhedral chloritised amphiboles with interstitial quartz, chlorite and opaques.

Plagioclase is brown, altered, euhedral to subhedral crystals, often zoned and sieve textured. Remnant unaltered crystal gives ML angle of 27, An%40, Andesine. Most other crystals are murky and brown, especially at rims, with some patchy saussuritisation to albite, sericite and epidote. Some crystals have outer rims of partly altered brown, low RI material which may be altered K-spar, as albite twins do not continue through it. About 55–60% of rock.

Quartz occurs as small, anhedral and sometimes granophyric grains interstitial to plagioclase, about 5%. K-spar is in granophryic intergrowth with quartz, also as brown stained rims on plagioclase. Estimate about 10-15%, norm gives 14%.

Mafic is pale green pleochroic amphibole, probably hornblende, from 2–3mm blocky elongate subhedral chloritised, some uralitised crystals down to fine 0.5mm and less interstitial anhedral grains in groundmass. 10–12%.

Opaques are partially oxidised magnetite, with pyrite, hematite and leucoxene alteration. About 10%. Trace apatite, and secondary chlorite, sericite, epidote, uralite and calcite as void filliing and alteration of other phases.

Field Number		Formation:					
WI40D		West Ibáñez Granitoid					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
274470	4858508		20	10	50	0	80
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
			10	5			
Other components:		Others:	Total:				
Calcite,epidote,etc.		5	100				
Final Rockname							
Propylitised microgranodiorite.							

Microscopic textures (WI40D):

Texture is hypidiomorphic, looks like a microgranitoid of some sort, but shows signs of extreme hydrothermal alteration — propylitisation.

Original mineralogy appears to have been quartz, sodic plagioclase, and a pyribole of some sort.

Quartz is unaltered, 20% anhedral, interstitial to feldspars, but the plagioclase is now either albitised or partly to completely replaced by sericite, calcite and epidote. Pyrite cubes are common. K spar, if present, is Altered, not identifiable, probably 10% or less.

Plagioclase pseudomorphs and remnants were euhedral to subhedral,o riginally 50% Altered, but identifiable as sodic plagioclase/albite from remnat albite twinned crystals, and pseudomorphs of zoning.

The quartz and mafics forming later more interstitial phases. Clusters of pyrite, epidote and purple-interference coloured chlorite occur, probably pycnochlorite or diabanite. Calcite is also common as a feldspar replacement.

Chlorite 5-10%, as alteration of mafics. Common calcite, Epidote, Pyrite, goethite, etc. Also Leucoxene.

Field Number		Formation:					
WI105 *		West Ibáñez Grauitoid					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
272830	4863430		15	5	65	0	85
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
		5	2	5			
Other components:		Others:	Total:				
Apatite/titanite/epidote, etc.		3	100				
Final Rockname							
Moderately altered hornblende micro-quartz monzodiorite/diorite. I type							

Microscopic textures (WI105):

Moderately altered plagioclase rich microgranitoid, with an equigranular texture of euhedral to subhedral plagioclase crystals, partly sericitised or even saussuritised, with interstitial quartz, green amphibole, chlorite (after biotite), magnetite, and secondary epidote, rutile, calcite, sericite, etc.

Plagioclase is euhedral to subhedral, 0.4 to 2mm, avg 0.8mm, which dominate the rock (about 60–65%). Cores are partly sericitised, and outer rims are qnite sodic, some may have K-spar rim (Trace to 5%.). Zoning occurs, but is usually simple normal zoning, though some crystals show repeated oscillatory zoning. ML on cores: 16, 5, 21.5, 13, 22, 23, 26, about An% 40,Andesine, bnt given the high level of alteration and occurrence of sericite, calcite and occasional epidote at the cores of most crystals, they were probably much more calcic before alteration, which appears to have had an albitisation effect. Possibly original plagioclase was Labradorite, zoned down to an andesine or calcic oligoclase rim.

Quartz is small, 0.4mm or less anhedral grains interstitial to the plagioclase. About 10–15%.

Mafics are green pleochroic hornblende, about 5%, subhedral, interstitial to the plagioclase and associated with opaques, 5% and about 2–4% green chlorite, as alteration of hornblende and also trace chloritised biotite. Opaque is magnetite. Also some titanite and apatite with mafics.

Alteration products include chlorite, sericite, epidote, calcite, fine grained fibrous green amphibole, perhaps uralite.

Field Number		Formation:					
WI38B *		West Ibáñez Granitoid					
Utm East	Utm North		Q:	A:	P:	F:	Subtotal:
274840	4857120		15	3	65	0	83
Cpx:	Opx:	Amph:	Chlorite:	Opaques:	Muscovite:	Biotite:	Olivine:
			10	5			
Other components:		Others:	Total:				
sericite, calcite, etc		2	100				
Final Rockname							
Altered micro-monzodiorite.							

Microscopic textures (WI38B):

Very altered microgranitic rock, with 60–65% sericitised and calcite replaced subhedral and euhedral plagioclase, with interstitial subhedral and anhedral quartz (10–15%) and green altered mafics.

Plagioclase phenocrysts subhedral to euhedral large crystals (0.5–2mm), in a matrix of finer subhedral microgranitic to framework or radial small plagioclase with interstitial anhedral quartz, opaques and altered mafics. Plagioclase is brown and altered with fine patches of sericite and calctite occurring within crystals, sometimes saussuritised with epidote and albitised plagioclase. About 65%. Difficult to tell if any k-feldspar remains due to alteration, Norm gives almost 3%.

Quartz is anhedral crystals interstitial to plagioclase, about 15%, sub 1mm.

Mafics are about 9–10%, blocky 0.2–1mm pseudomorphs of amphibole, now green pleochoic chlorite, with some calcite and opaque alteration.

Opaque minerals are uniformly altered to white leucoxene or hematite, also about 5%, associated with mafics. Some skeletal, anhedral crystals suggest presence of some ilmenite, as well as blocky patches ofhematite after magnetite.

A bit altered for good QAPF estimation.

Appendix B

Chemical Analysis

Table B.1: Table of major chemical elements (%)

Field no	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	LOI	Total
Basement Schists												
SCH5A	18.98	0.36	7.33	6.1	0.65	1.96	32.81	2.23	0.15	0.48	28.77	99.81
Ibáñez Formation												
Silicic Pyroclastic Rocks												
F9B	70.33	0.26	14.34	2.75	0.05	0.61	2	3.57	3.04	0.07	3.23	100.23
WI56	74.75	0.19	13.47	2.16	0.03	0.26	0.15	2.4	5.33	0.05	1.17	99.96
WI7	85.17	0.24	5.07	2.09	0.04	0.46	1.24	1.26	1.19	0.12	2.07	98.95
WI72	78.49	0.25	11.08	2.3	0.04	0.45	0.27	4.75	1.45	0.07	0.61	99.76
F9T	73.09	0.24	13.53	2.43	0.04	0.3	1.21	3.62	3.54	0.07	1.93	99.98
F11T	73.59	0.22	13.2	2.42	0.03	0.24	1.13	3.18	4	0.06	1.8	99.88
WI21	77.58	0.17	11.27	1.73	0.009	0.11	0.11	0.23	7.77	0.05	1.3	100.329
L5β	72.24	0.19	12.74	2.28	0.05	0.28	2.31	2.65	4.14	0.05	3.01	99.94
PI43T	73.79	0.28	13.91	2.35	0.05	0.5	0.93	6.09	1.32	0.06	0.84	100.09
F11M	71.66	0.24	13.47	2.4	0.05	0.38	2.44	4.06	2.17	0.06	3.17	100.09
F23	75.41	0.26	13.23	2.72	0.02	0.34	0.26	2.71	3.55	0.06	1.68	100.24
WI9	74.88	0.23	13.24	2.57	0.01	0.29	0.25	3.5	4.33	0.06	1.04	100.4
F9M	72.79	0.24	13.64	1.61	0.04	0.34	1.84	3.27	3.22	0.06	2.9	99.95
L20	75.56	0.16	13.31	2.04	0.04	0.28	0.23	2.84	4.59	0.04	1.23	100.33
F57A	76.01	0.15	10.24	1.76	0.07	0.46	2.45	2.41	3.16	0.03	3.08	99.82
PI43M	72.65	0.26	13.59	2.58	0.06	0.83	1.38	4.07	2.65	0.06	2.24	100.37
PI43B	76.59	0.2	11.5	2.09	0.04	0.52	1.27	3.61	2.44	0.05	1.95	100.25
L20α	74.34	0.24	13.02	2.86	0.04	0.2	0.56	3.69	3.51	0.06	1.37	99.89
F11B	75.25	0.24	13.68	2.17	0.01	0.34	0.24	1.28	4.69	0.06	1.92	99.87
PI79B	76.28	0.25	11.33	2.24	0.03	0.65	1.63	3.57	2.74	0.05	1.54	100.31
F2A	67.33	0.33	13.73	2.92	0.06	0.57	3.12	2.94	3.12	0.1	4.48	98.7
Silicic Extrusive Rocks (Including Cerro Cabeza Blanca)												
WI41	59.97	0.68	15.42	6	0.14	0.81	5.48	2.87	2.69	0.23	5.8	100.09
WI111	63.39	0.77	15.93	5.57	0.15	1.36	1.87	6.1	2.94	0.23	1.66	99.96
WI113	78	0.49	14.06	3.93	0.1	0.23	2.24	0.75	8.25	0.14	2.69	99.64
WI33	64.63	0.59	15.55	4.84	0.09	0.55	2.97	3.47	4.22	0.19	3.26	100.36
WI25	78.23	0.11	11.71	1.59	0.01	0.27	0.17	0.86	5.97	0.02	1.43	100.37
GA11C	74.15	0.2	13.82	0.98	0.02	0.2	1.33	4.03	2.83	0.05	2.35	99.95

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Table B.1: Table of major chemical elements *continued*

Field no	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	LOI	Total
F18	78.06	0.11	12.19	1.4	0.01	0.26	0.16	1.18	5.54	0.03	1.02	99.96
F22	73.87	0.09	13.09	1.54	0.02	0.14	0.19	4.05	4.77	0.02	0.71	98.49
WI76	76.14	0.09	10.98	1.27	0.04	0.19	1.59	1.56	5.29	0.02	2.21	99.38
L14	69.83	0.27	13.98	3.58	0.1	0.19	1.88	1.04	5.83	0.05	3.24	99.99
CP20	75.67	0.14	13.82	1.32	0.03	0.1	0.11	0.17	6.72	0.03	1.59	99.68
CP68	67.66	0.15	17.17	2.28	0.01	0.15	0.09	0.18	10.8	0.02	1.37	99.87
CF19B	64.84	0.47	16.86	4.34	0.09	1.87	4.13	4.93	1.36	0.16	0.95	100
WI120	77.93	0.08	12.4	1.52	0.03	0.22	0.12	0.29	5.41	0.02	1.78	99.79
Basaltic and Basaltic Extrusive Rocks												
WI99	48.55	1.26	16.98	11.02	0.17	6.26	10.3	2.07	0.48	0.32	2.66	100.07
F28	53.52	1.18	19.5	7.38	0.11	2	8	3.57	1.8	0.34	2.54	99.94
WI86A	50.92	1.2	16.56	10.3	0.2	6.58	9.6	2.22	0.86	0.34	1.22	99.99
CP24A	45.6	1.19	16.92	7.54	0.25	2.6	12.48	2.62	2.22	0.36	8.34	100.1
WI82B	46.07	1.08	16.95	9.82	0.19	6.57	8.93	3.13	0.2	0.28	6.89	100.11
F38	54.21	0.62	17.17	6.84	0.17	2.06	4.92	8.77	0.92	0.3	4.42	100.4
GA10B	53.31	1.17	18.35	6.63	0.09	1.86	2.99	6.75	2.47	0.35	6.05	100.02
WI86C	37	1.15	16.2	10.13	0.18	7.04	8.35	2.58	0.19	0.34	6.46	99.99
PI18	53.54	1.03	17.09	8.17	0.15	5.14	7.57	3.21	1.5	0.33	2.14	99.87
CP18A	49.2	1.05	16.25	11.77	0.26	7.94	3.71	4.05	3.75	0.23	1.47	99.69
PI22	55.77	1.04	16.92	9.06	0.14	4.57	2.64	6.09	1.15	6.34	2.4	100.12
Divisadero Formation												
Tuffs and Ignimbrites												
CD12B	76.81	0.1	12.21	1.55	0.06	0.19	0.49	2.99	4.53	0.02	0.91	99.86
LC4	76.38	0.1	12.8	1.18	0.02	0.26	0.26	2.9	4.99	0.02	1.07	99.98
CF39	74.51	0.18	13.1	1.33	0.06	0.29	1.21	3.93	3.74	0.04	1.57	99.97
F48	73.36	0.22	13.66	2.18	0.04	0.13	0.61	2.97	4.55	0.05	1.65	99.42
CD12M	76.54	0.1	12.6	1.4	0.06	0.33	0.5	2.93	4.57	0.02	1.07	100.11
CD7T	77.33	0.15	11.63	1.44	0.03	0.05	0.25	2.72	5.5	0.03	0.65	99.73
CD7M	75.27	0.17	13.21	1.49	0.03	0.08	0.19	4.28	4.46	0.04	0.62	99.83
CD7B	77.34	0.12	11.86	1.51	0.03	0.05	0.16	3.86	4.53	0.03	0.29	99.7
LF5T	76.39	0.1	12.68	0.99	0.04	0.15	0.42	3.58	4.57	0.02	0.9	99.83
LF5M	76.58	0.1	12.6	0.97	0.04	0.18	0.52	3.17	4.58	0.02	1.2	99.95
GA1	77.13	0.18	13.37	1.34	0.07	0.12	0.09	0.18	3.42	0.05	3.8	99.73
LF5B	75.9	0.11	13.09	0.92	0.03	0.11	0.39	3.63	5.06	0.02	1.15	100.41
LF4T	76.17	0.21	12.41	1.97	0.04	0.24	0.7	2.92	4.03	0.03	1.19	99.91
LC1	77.41	0.11	11.96	0.99	0.07	0.29	0.73	2.75	4.04	0.03	1.46	99.83
LC3	76.3	0.1	12.29	1.13	0.04	0.25	0.9	2.38	5.04	0.02	1.59	100.03
LF4M	75.53	0.22	12.8	2	0.08	0.22	0.56	3.66	3.75	0.04	1.19	100.04
F50	74.65	0.21	13.21	1.98	0.07	0.41	1.03	2.13	4.15	0.05	2.53	100.42
LF4B	74.6	0.21	12.62	1.97	0.08	0.21	1.17	3.54	3.97	0.04	1.3	99.71
F27A	69.1	0.24	13.29	2.53	0.21	0.23	2.62	2.49	4.16	0.06	4.18	99.11
LC2	77.62	0.11	12.53	1.02	0.03	0.21	0.17	1.91	5.04	0.02	1.38	100.03

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Table B.1: Table of major chemical elements *continued*

Field no	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	LO1	Total
CD12T	76.59	0.11	12.5	1.31	0.06	0.27	0.58	3.05	4.57	0.03	0.9	99.95
Andesitic Lavas												
Cerro Pico Rojo Rhyolite Dome												
Pumice Flow Unit												
F53	74.8	0.17	12.52	2.57	0.06	0.2	0.24	4.35	4.67	0.03	0.3	99.91
F51A	75.98	0.15	10.96	3.27	0.02	0.2	0.16	4.25	4.24	0.03	0.51	99.77
GA5	76.49	0.2	11.05	3.12	0.01	0.05	0.06	0.99	6.33	0.03	1.44	99.7
GA7	76.21	0.13	12.54	1.46	0.01	0.05	0.03	3.84	5.06	0.01	0.7	99.98
F51B	74.55	0.13	10.76	3.7	0.02	0.44	0.35	3.03	4.33	0.03	1.67	99.01
S7	76.2	0.11	11.74	2.39	0.03	0.05	0.07	4.69	4.31	0.02	0.33	99.88
S8	76.03	0.11	11.68	2.55	0.06	0.05	0.07	4.58	4.53	0.03	0.2	99.83
S2	73.53	0.14	11.21	2.73	0.01	0.06	1.78	2.13	3.57	0.02	4.76	99.94
Plateau Basalts												
S9A	52.63	1.99	16.97	9.41	0.21	3.77	7.78	4.17	1.5	0.71	0.59	99.74
S10A	49.25	2.31	16.61	11.14	0.26	5.08	8	3.74	1.55	0.58	1.5	100.01
S10B	47.29	3	15.15	11.63	0.15	6.93	8.98	2.96	1.08	0.72	1.92	99.79
Minor Intrusive Rocks												
Undersaturated Basaltic Minor Intrusive Rocks												
F11	45.49	2.14	17.14	9.91	0.26	3.91	9.64	4.44	2.2	0.92	3.98	100.03
F45	43.04	2.06	15.08	9.33	0.18	4.68	12.62	3.26	2.36	0.71	5.33	98.65
Basaltic, Basaltic andesitic, Trachybasaltic/andesitic and Andesitic Minor Intrusive Rocks												
L17B	56.39	0.85	17.23	5.39	0.09	3.48	6.28	4.44	0.89	0.28	4.59	99.91
WI46B	59.54	0.94	16.18	6.86	0.12	1.79	6.41	2.96	1.05	0.36	3.55	99.76
F1	54.18	1.13	16.21	7.95	0.23	2.13	6.57	4.84	0.52	0.6	5.91	100.27
F10	53.68	1.01	15.79	7.4	0.19	1.7	6.4	3.19	1.21	0.54	8.83	99.94
WI30	55.17	0.72	18.4	6.34	0.13	3.61	7.39	3.98	0.64	0.18	2.69	99.25
WI1	47.51	1.12	16.48	8.83	0.28	3.52	10.42	1.98	2.11	0.48	7.23	99.96
F20	45.6	1.57	17.21	8.19	0.1	2.78	7.03	2.9	1.89	0.7	12.43	100.4
WI24	53.23	1.34	18.35	9.12	0.13	2.77	5.35	4.9	1.91	0.28	2.49	99.87
F21	48.94	2.36	15.72	12.64	0.32	4.11	5.18	5.41	0.74	0.91	4.01	100.34
L17A	57.57	0.9	17.57	5.54	0.08	3.18	3.49	8.43	0.48	0.28	2.55	100.07
F8C	58.34	1.1	17.88	7.02	0.21	2.76	1.5	6.88	2.02	0.34	2.42	100.47
F2C	53.52	1.23	16.62	8.63	0.16	2.2	4.49	6.71	0.93	0.5	5.11	100.1
F5A	53.15	0.91	15.15	8.41	0.14	6.67	3.51	3.27	1.74	0.28	6.27	99.5
F39B	53.45	1.15	16.93	8.76	0.32	5.71	3.35	5.4	0.55	0.32	3.72	99.66
F29	55.31	0.67	17.73	7.03	0.25	3.17	3.91	5.13	3.5	0.35	3.38	100.43
F33	60.41	0.67	17.82	5.45	0.07	2.45	6.05	3.88	1.31	0.19	2.07	100.37
S3	61.09	0.74	17.2	5.92	0.12	2.86	6.19	3.82	1.59	0.15	0.26	99.94
S6	54.99	0.87	19.06	7.69	0.19	3.8	8.42	3.65	0.78	0.22	0.43	100.09
LH12	55.34	1.55	15.61	10.58	0.2	3.03	6.96	3.47	2.07	0.54	0.4	99.75
F64A	52.43	1.42	16.21	10.15	0.18	2.44	6.7	3.7	3.03	0.49	3.07	99.82
F68	49.34	1.33	16.03	9.65	0.18	2.06	8.44	3.26	2.55	0.47	6.81	100.12

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Table B.1: Table of major chemical elements *continued*

Field no	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	LOI	Total
F69	50.82	1.54	15.47	10.09	0.17	2.87	6.48	4.06	2.85	0.54	4.67	99.56
F27B	54.36	1.31	18	8.79	0.17	2.4	7.5	3.69	2.33	0.5	0.26	99.31
Phonolitic Minor Intrusives												
L5α	56.13	0.04	19.78	4.14	0.14	0.049	0.67	10.01	4.96	0.05	4.18	100.149
Dacitic and Rhyolitic Minor Intrusives												
CP46A	65.11	0.62	15.16	3.89	0.07	1.94	3.04	3.87	3.19	0.19	3.27	100.35
WI43	62.11	0.78	15.91	5.37	0.12	0.74	5.86	3.56	2.68	0.26	2.42	99.81
CP17C	64.86	0.42	14.86	3.63	0.09	1.5	3.62	3.61	2.79	0.15	4.27	99.8
F57B	65.27	0.3	14.58	3.62	0.12	0.85	3.05	4.34	1.57	0.18	5.26	99.14
F61	63.63	0.63	16.73	5.68	0.1	1.78	4.24	4.9	1.27	0.32	0.52	99.8
CP48	64.11	0.77	15.59	4.14	0.15	1.55	3.19	4.64	2.77	0.28	3.13	100.32
F59	62.33	0.63	15.61	5.09	0.14	1.09	4.17	4.46	1.27	0.26	5.25	100.3
F58	66.31	0.39	15.77	4.47	0.15	1.01	2.55	5.72	1.54	0.24	2.08	100.23
PI79A	62.05	0.51	16.76	4.47	0.1	2.56	4.11	4.61	1.46	0.16	3.53	100.32
WI17	60.94	0.54	17.15	4.5	0.1	2.8	3.01	5.94	1.45	0.16	3.48	100.07
WI10	69.45	0.24	15.49	2.9	0.05	0.59	1.55	6.38	1.73	0.14	1.97	100.49
F14	72.54	0.22	13.47	2.04	0.07	0.3	2.54	2.72	2.32	0.08	3.8	100.1
WI22	71.24	0.28	14.8	2.78	0.05	0.5	1.5	4.67	2.07	0.09	2.44	100.42
F12	72.81	0.23	13.63	2.7	0.07	0.43	1.2	2.72	4.19	0.07	1.84	99.89
F44A	63.08	0.55	15.26	4.68	0.16	1.19	2.57	5.67	1.57	0.22	4.78	99.73
F40	64.06	0.62	15.89	4.92	0.17	1.45	2.31	6.28	1.31	0.25	1.53	98.79
F47	62.72	0.86	15.72	6.49	0.1	1.23	4.38	4.52	0.47	0.36	3.08	99.93
F64B	63.53	0.75	15.9	5.26	0.11	1.43	2.65	6.14	1.81	0.26	2.19	100.03
Granitoids and Microgranitoids												
CF27	69.98	0.31	14.76	2.85	0.07	1.09	3.01	3.53	3.49	0.08	0.71	99.88
CF19C	54.32	0.93	16.67	8.84	0.23	5.1	6.76	4.22	1.73	0.13	1.17	100.11
CF20	66.74	0.43	16.28	4.33	0.03	1.82	4.17	4.23	1.24	0.12	0.83	100.23
CF24	68.32	0.4	16.71	2.28	0.03	1.49	3.99	4.5	1.34	0.14	0.75	99.94
CF25	62.62	0.56	16.89	6.48	0.04	2.49	4.41	3.32	1.83	0.15	0.65	99.43
CF26	62.31	0.63	16.77	5.52	0.11	2.69	5.32	3.76	1.7	0.16	1.14	100.1
CF16	61.47	0.59	16.61	5.35	0.06	2.54	4.83	4	1.71	0.15	2.08	99.38
CF41C	63.84	0.58	16.3	4.98	0.07	2.33	4.95	3.93	1.74	0.15	0.91	99.78
CF15	64.1	0.53	16.47	4.95	0.1	2.26	4.94	3.74	1.68	0.15	0.93	99.84
CF6A	63.15	0.55	16.85	4.61	0.06	2.69	5.64	4.29	1.22	0.16	0.92	100.14
CF6B	64.39	0.54	16.26	4.54	0.07	2.26	4.82	4.14	1.8	0.15	0.91	99.88
CP61	66.11	0.41	16.31	3.61	0.08	1.74	3.73	4.91	1.17	0.13	0.4	98.6
GA15A	63	0.55	17.42	4.72	0.09	2.44	5.29	4.53	1.08	0.16	0.93	100.22
CP62	67.24	0.42	16.39	3.42	0.07	1.59	2.85	5.24	1.49	0.14	0.97	99.82
CP52	64.97	0.4	15.61	3.55	0.07	1.63	2.75	5.71	0.96	0.13	2.87	98.65
PI89	64.69	0.49	16.23	3.81	0.1	1.97	3.83	5.02	1.36	0.14	2.69	100.33
CP60	57.99	1.61	16.22	7.78	0.17	2.83	5.45	4.17	2.58	0.61	0.91	100.32
BERT1	68.34	0.25	16.33	2.75	0.06	0.75	4.05	3.34	2.6	0.05	1.44	99.97

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Table B.1: Table of major chemical elements *continued*

Field no	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	LOI	Total
Esmeralda												
	64.63	0.58	15.61	5.44	0.06	1.96	4.42	3.05	2.44	0.12	1.17	99.47
PI75A	57.98	0.54	16.2	4.34	0.12	2.06	5.79	3.8	2.5	0.17	6.7	100.2
PI62	63.29	0.62	16.36	5.24	0.11	2.31	4.75	4.09	1.94	0.19	1.55	100.45
PI23	62.92	0.65	16.15	5.36	0.12	2.29	4.93	4.07	1.79	0.19	1.76	100.22
CP77	53.44	1.07	18.08	9.14	0.17	3.87	7.52	3.87	1.01	0.26	1.51	99.95
CP83	56.18	1.07	17.26	8.46	0.21	3.12	6.31	4.01	1.35	0.39	1.63	99.99
WI105	60.52	0.62	17.64	5.43	0.07	2.65	5.08	5.01	1.18	0.21	1.61	100.01
WI95C	61.33	0.59	17.26	5.31	0.12	2.67	5.32	4.25	0.96	0.2	2.27	100.27
WI47	52.76	1.06	15.99	8.83	0.17	4.39	4.59	4.14	2.22	0.31	1.92	96.38
WI38B	61.64	0.76	15.21	4.9	0.07	2.93	4.76	5.61	0.47	0.22	3.89	100.46

Table B.2: Table of trace chemical elements (parts per million)

Field no	Ga	Pb	Rb	Sr	Th	Y	V	Cr	Ni	Zn	Zr	Nb	Ba	La	Ce	Nd
Basement Schists																
SCH5 A	10	1	1	1915	4	27	84	42	20	79	86	10	70	25	63	43
Ibáñez Formation																
Silicic Pyroclastic Rocks																
F9B	17	13	122	248	20	21	30	115	5	39	165	7	634	41	83	32
WI56	14	18	175	38	18	21	22	2	4	40	121	6	1084	34	59	27
WI7	11	4	99	28	4	13	42	3	2	53	74	2	100	5	7	13
WI72	10	18	74	102	10	21	27	4	4	75	153	5	362	26	51	30
F9T	14	11	123	292	20	19	26	10	3	39	155	8	1016	42	74	36
F11T	14	14	144	139	13	21	26	12	3	39	141	7	1117	41	77	36
WI21	13	19	354	34	14	23	39	2	4	26	94	6	752	28	60	24
L5β	14	13	145	112	11	20	21	11	4	36	115	6	987	27	58	21
PI43T	12	15	63	294	9	21	40	7	4	32	124	6	510	21	54	20
F11M	15	13	108	160	20	19	25	10	4	40	158	7	488	42	77	34
F23	13	15	126	101	15	17	20	2	4	43	147	5	858	50	91	38
WI9	12	17	166	77	15	18	33	2	3	25	137	6	1866	29	49	21
F9M	18		106	158	20	21	25	5	3	40	165	8	751	48	87	32
L20	14	13	150	94	13	22	18	6	3	36	113	6	1368	26	68	39
F57A	10	15	138	141	12	19	26	2	3	62	98	5	530	29	52	30
PI43M	16	7	145	170	7	14	46	14	4	52	109	4	490	17	44	30
PI43B	11	35	121	157	8	18	34	9	5	39	94	5	603	26	42	20
L20α	14	15	131	114	11	21	26	5	4	33	150	7	1012	39	63	20
F11B	15	18	188	73	12	21	27	17	3	37	158	6	923	45	86	31
PI79B	9	20	94	492	16	22	34	6	4	54	159	5	1006	25	52	26
F2A	18	17	168	115	11	24	39	6	3	53	157	5	422	26	46	31
Silicic Extrusive Rocks (Including Cerro Cabeza Blanca)																
WI41	17	8	119	156	13	35	58	13	5	84	226	8	600	32	72	42
WI111	19	10	104	262	6	36	47	8	3	86	234	10	542	24	64	38
WI113	17	24	355	75	10	32	49	19	5	92	236	4	1569	30	68	34
WI33	20	9	179	184	13	36	40	9	5	59	248	8	880	28	59	32
WI25	13	10	212	36	14	20	13	2	2	21	84	5	819	28	57	26
GA11C	13	12	71	510	18	16	22	10	3	20	152	8	989	35	71	21
F18	13	16	247	78	21	22	26	2	3	40	94	7	873	36	58	23
F22	12	19	136	95	24	20	14	2	2	42	101	7	1187	38	61	22
WI76	12	73	216	70	13	25	12	3	2	41	71	5	783	26	45	26
L14	24	19	232	96	13	50	8	2	4	106	297	8	898	37	75	36
CP20	19	24	264	60	17	45	15	6	4	42	167	8	1070	141	113	143
CP68	21	12	466	69	19	53	19	8	4	39	201	7	902	37	66	44
CF19B	17	14	39	507	3	12	81	19	11	84	109	7	270	8	38	18
WI120	14	3	226	66	18	21	16	15	3	20	97	7	1087	35	66	37

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Table B.2: Table of trace chemical elements *continued*

Field no	Ga	Pb	Rb	Sr	Th	Y	V	Cr	Ni	Zn	Zr	Nb	Ba	La	Ce	Nd
Basaltic and Basaltic Extrusive Rocks																
WI99	18	5	4	405	1	26	213	206	73	92	143	10	243	14	50	35
F28	20	11	65	479	9	24	139	18	6	66	161	7	484	24	49	33
WI86A	18	1	19	348	3	27	207	282	83	96	148	9	388	18	58	35
CP24A	18	8	84	374	3	27	225	188	65	90	151	8	472	15	62	30
WI82B	18	17	1	386	3	24	278	438	125	142	124	8	181	12	34	26
F38	13	7	19	342	9	18	181	9	8	65	129	5	559	22	49	23
GA10B	19	1	70	646	7	26	136	7	3	54	173	8	808	24	63	37
WI86C	18	12	1	353	3	27	255	419	113	89	134	9	136	12	35	39
PI18	18	6	60	516	5	23	180	208	65	88	186	8	400	15	55	36
CP18A	16	13	447	267	2	19	276	210	87	256	90	2	269	5	27	25
PI22	17	9	32	598	7	26	173	147	52	86	178	9	1085	12	54	28
Divisadero Formation																
Tuffs and Ignimbrites																
CD12B	11	20	165	39	17	21	14	8	4	28	80	6	1094	32	55	22
LC4	12	22	186	55	15	20	18	8	3	24	84	6	1115	34	63	24
CF39	12	15	81	152	13	30	18	14	3	39	152	8	1273	27	56	28
F48	13	13	143	69	13	28	20	2	4	44	170	6	1299	26	55	24
CD12M	12	17	167	43	20	20	16	7	3	27	84	6	1082	34	63	34
CD7T	11	24	120	16	10	40	17	6	5	31	137	9	1295	36	71	38
CD7M	13	15	136	42	12	43	17	8	4	34	146	9	1001	44	97	44
CD7B	12	19	123	36	14	46	17	4	3	35	124	9	939	38	83	36
LF5T	10	17	170	46	18	20	15	4	4	24	85	6	1161	38	61	20
LF5M	11	16	169	45	18	20	16	6	4	23	84	6	1103	39	56	22
GA1	14	4	95	16	12	37	20	9	3	32	150	8	1116	35	64	39
LF5B	11	17	135	37	20	20	20	5	3	21	88	7	1342	30	55	39
LF4T	13	21	158	65	11	45	17	9	3	44	205	7	854	32	62	51
LC1	10	20	165	104	15	21	18	8	3	24	86	6	1599	30	54	24
LC3	11	19	210	66	15	20	17	10	3	26	84	6	1121	33	58	28
LF4M	13	21	138	60	12	44	17	6	3	44	215	8	831	31	58	44
F50	15	16	143	139	19	30	21	3	3	49	158	9	601	46	88	31
LF4B	13	20	127	58	8	41	16	6	3	45	210	7	836	26	67	39
F27A	14	22	125	93	15	31	31	2	3	53	162	5	997	28	54	29
LC2	11	14	203	55	16	18	16	7	4	28	86	6	1128	33	58	27
CD12T	12	16	169	45	18	21	16	17	3	27	87	7	1113	34	54	33
Andesitic Lavas																
Cerro Pico Rojo Rhyolite Dome																
Pumice Flow Unit																
F53	32	32	253	19	34	144	15	2	4	182	1004	149	32	72	152	73
F51A	34	22	269	11	45	142	11	2	4	214	1879	177	20	73	222	86
GA5	32	14	313	11	21	113	15	5	4	69	1077	117	73	107	229	117
GA7	30	8	270	3	29	117	13	11	5	68	1179	139	20	17	73	38

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Table B.2: Table of trace chemical elements *continued*

Field no	Ga	Pb	Rb	Sr	Th	Y	V	Cr	Ni	Zn	Zr	Nb	Ba	La	Ce	Nd
F51B	33	33	248	23	38	169	11	2	3	265	1733	163	23	106	243	117
S7	29	20	209	4	28	123	14	5	3	132	1050	137	20	18	73	44
S8	30	24	223	7	26	100	17	4	6	85	1032	123	26	53	139	63
S2	28	16	157	91	20	92	14	3	3	103	936	111	22	49	137	60
Plateau Basalts																
S9A	23	2	21	544	4	36	256	9	11	103	284	26	386	28	75	46
S10A	20	1	28	421	4	38	223	56	30	87	277	44	324	28	70	47
S10B	21	4	23	445	13	38	210	225	129	99	304	32	217	17	77	55
Minor Intrusive Rocks																
Undersaturated Basaltic Minor Intrusive Rocks																
F11	16	7	44	846	7	28	120	83	42	73	271	69	843	70	117	51
F45	16	6	43	764	6	24	144	255	127	62	198	63	584	47	81	45
Basaltic, Basaltic andesitic, Trachybasaltic/andesitic and Andesitic Minor Intrusive Rocks																
L17B	22	4	25	1548	3	10	104	25	20	42	118	3	110	19	59	29
WI46B	19	17	29	418	10	34	79	11	5	93	303	12	503	44	96	50
F1	19	5	11	374	3	31	44	9	2	75	161	6	168	16	37	40
F10	17	6	29	320	2	30	29	16	4	65	160	6	351	20	43	26
WI30	21	61	13	810	3	11	132	38	18	221	106	3	114	12	22	15
WI1	18	11	81	452	5	26	182	89	39	83	156	8	587	25	59	35
F20	23	7	36	1316	4	19	145	24	16	98	245	25	443	31	77	41
WI24	23	8	87	545	5	27	193	8	7	121	150	4	324	14	32	25
F21	21	7	11	456	5	42	319	23	10	100	208	7	485	26	58	36
L17A	24	4	14	854	5	10	109	31	21	47	126	2	53	21	54	36
F8C	20	14	81	318	11	29	120	6	5	97	186	6	600	22	44	32
F2C	17	4	24	532	3	26	67	9	4	70	142	5	312	8	29	25
F5A	13	9	49	290	6	21	176	280	72	83	128	6	3083	23	48	22
F39B	19	6	7	365	4	20	219	34	10	65	162	8	428	16	44	22
F29	12	7	95	558	10	24	105	3	6	68	151	6	2445	30	54	26
F33	18	7	34	534	6	16	98	46	21	60	130	4	278	13	27	25
S3	19	3	50	571	3	22	127	34	16	54	137	6	319	15	30	32
S6	19	1	11	543	1	21	157	50	34	65	90	7	190	7	29	21
LH12	20	11	55	537	18	45	214	3	3	88	232	10	520	17	69	40
F64A	22	11	121	332	11	41	235	14	11	67	215	6	494	26	61	37
F68	19	10	100	421	10	38	248	16	10	83	206	7	452	24	55	33
F69	19	8	109	347	11	44	231	4	5	83	214	7	671	25	68	35
F27B	19	10	87	461	12	39	151	3	6	69	218	7	470	25	63	41
Phonolitic Minor Intrusives																
L5α	48	13	121	6	22	34	9	2	3	224	1561	140	20	124	214	61
Dacitic and Rhyolitic Minor Intrusives																
CP46A	18	11	114	420	15	17	83	12	13	59	149	6	406	26	49	27
WI43	17	16	74	498	12	35	55	5	4	76	237	8	1076	32	78	39
CP17C	16	16	101	227	13	15	66	25	8	97	137	5	392	25	49	23

continued on next page

Table B.2: Table of trace chemical elements *continued*

Field no	Ga	Pb	Rb	Sr	Th	Y	V	Cr	Ni	Zn	Zr	Nb	Ba	La	Ce	Nd
F57B	16	8	48	407	5	22	14	2	2	63	165	8	313	22	52	31
F61	17	6	35	442	4	22	42	2	4	49	177	7	319	22	48	27
CP48	19	39	91	297	15	27	54	5	5	116	210	9	360	32	63	35
F59	19	5	31	374	4	28	36	7	4	70	217	8	363	24	59	37
F58	16	7	37	436	6	24	17	2	3	59	176	9	405	24	64	34
PI79A	19	7	41	777	4	10	81	41	17	55	86	3	398	8	21	12
WI10	17	11	62	116	6	12	13	2	3	55	157	8	240	16	33	23
F14	13	10	90	104	19	14	20	3	2	40	120	5	1042	29	50	26
WI22	16	14	61	191	7	15	18	6	3	88	186	9	472	21	41	21
F12	13	18	160	137	20	18	20	8	4	45	140	6	1290	33	59	19
WI17	18	14	39	607	3	6	81	20	14	79	105	3	455	7	15	12
F44A	19	6	54	314	6	29	28	2	2	67	225	7	387	23	58	33
F40	18	6	31	480	5	28	29	2	2	61	220	7	426	20	41	33
F47	17	8	7	250	3	27	35	3	4	64	233	9	266	22	57	38
F64B	17	10	59	240	5	33	32	2	2	54	255	8	408	25	61	38
Granitoids and Microgranitoids																
CF27	15	11	107	333	16	18	47	19	7	38	103	7	570	21	50	20
CF19C	17	8	54	436	1	32	213	45	24	112	60	6	218	5	26	25
CF20	17	6	50	522	5	11	73	17	12	36	105	7	251	21	50	33
CF24	16	8	61	485	4	9	63	20	5	43	93	6	256	8	22	20
CF25	19	2	92	500	2	15	95	23	13	46	95	7	214	15	38	18
CF26	18	6	49	480	4	20	106	38	17	44	122	7	366	16	37	19
CF16	17	3	64	481	6	15	105	43	17	51	113	8	286	9	31	15
CF41C	17	4	47	480	4	21	85	26	18	48	147	7	412	16	39	28
CF15	17	7	52	476	6	18	82	34	12	64	126	7	372	21	44	28
CF6A	18	8	47	648	13	13	91	40	29	35	119	6	220	6	24	23
CF6B	18	9	55	514	14	18	79	31	20	38	142	7	377	9	40	22
CP61	19	4	24	524	5	10	52	8	12	48	97	4	306	10	14	19
GA15A	16	1	13	569	2	13	79	28	13	42	92	6	286	12	33	20
CP62	16	5	36	651	4	11	53	10	9	32	103	5	339	7	18	17
CP52	17	6	34	382	5	10	57	8	8	56	94	4	261	9	15	12
PI89	17	6	32	474	5	8	73	22	12	48	90	5	332	10	21	16
CP60	21	10	83	548	10	50	109	6	8	83	284	11	294	34	91	61
BERT1	15	18	104	191	7	12	65	19	3	40	69	5	462	21	40	21
Esmeralda																
	17	7	84	253	8	22	100	35	7	32	124	8	796	17	53	21
PI75A	18	18	103	317	3	11	92	62	28	198	93	4	166	11	19	17
PI62	19	10	61	454	9	18	75	14	7	47	122	4	313	15	32	19
PI23	16	3	58	453	5	20	100	19	7	56	141	7	371	14	42	32
CP77	21	1	24	500	3	20	180	14	3	75	59	7	198	8	37	23
CP83	23	8	44	442	6	27	108	6	7	85	150	7	270	16	43	35
WI105	18	1	27	630	2	15	90	28	16	51	115	9	186	7	27	25

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Table B.2: Table of trace chemical elements *continued*

Field no	Ga	Pb	Rb	Sr	Th	Y	V	Cr	Ni	Zn	Zr	Nb	Ba	La	Ce	Nd
WI95C	18	6	20	560	1	16	75	27	16	59	126	11	230	8	23	30
WI47	18	4	79	384	10	27	194	72	15	54	196	6	793	22	51	27
WI38B	16	5	24	322	15	21	123	84	21	25	200	7	31	19	48	25

Appendix C

Correspondence

Author = Aguirre-Urreta, Maria B
Title = Ammonites, E-mail 6 May 1998
Month = 6 May 1998
Buenos Aires, May 6, 1998.
Dear Zane,
Yesterday I received your letter & photos. I have just arrived a day before from a field trip to the Neuquen basin where I am working in Lower Cretaceous rocks & ammonites. To my complete surprise, I discover that some of your ammonites (and the inoceramids) are identical to the fauna I have just collected in Neuquen. Up to the present, most people believed that coeval faunas from the Neuquen and Austral basin were different. I had some doubts about that, specially since last year we found some Late Valanginian ammonites common to both basins (I will send a pre-print copy of the paper), and now your findings confirm that at some levles there is a close link between both basins.

There are three different ammonites: as you suspect, two are species of Crioceratites, of the Crioceratites nolani/duvali group of Europe, with local names in Argentina that characterizes the "mid" Hauterivian of the Boreal Realm, or the early-late Hauterivian boundary of the Tethys. I have doubts regarding your third form which seems to be the most common one. I would like you to tell me how is the whorl section (rounded, subquadrate, compressed, depressed), and if the ribs cross the venter with or without interruption and how (straight or curved backward or forward) and if there is any hint of tubercles. Any chance to see a suture line?.

I think the fossils are very important and deserve a publication. Let me know your opinion about that, as I do not know exactly the scope of your work in Chile.

Hope to hear from you soon.
Best regards,
Beatriz Aguirre-Urreta

Author = Aguirre-Urreta, Maria B
Title = Ammonites, E-mail 16 December 1998
Month = 16 December 1998,
Dear Zane,
Last week I finished with the teaching of the second semester and started immediately to look at your ammonites. As you recall you have three different forms, the msot common one was the one I have some doubts, and then two species of Crioceratites, which are nearly identical with two species quite common in the Neuquen basin, in northern Patagonia.

The common forms fits well with the diagnosis of Aegocrioceras, a genus only know in northwestern Europe, specially in Speeton Clay in UK and also in Germany, In fact, it is very important, and quite strange tō have this form in southern Patagonia. But it is not the first case of this funny distribution, we also have in the Austral basin, Protaconoceras, another Hauterivian genus that show the very same distribution. Up to the moment, we have none of these two genus in the Neuquen basin. It would be very important to the paleontology and biostratigraphy of the basin to be able to find the stratigraphic relationship of your fauna and the Favrella. I have written to Manuel Suarez about this problem, and also asking him if I could get more specimens from Chile but I did not get a reply. I would like to know if you are planning to go back again to the field this next summer, and if so, what is the chance of meeting a few days to visit the locality?. I could manage some days in Mid-Late February-early March. Iwill be in Buenos Aires till the first week on January. Hope you are progressing with your thesis, and that the information taht I can provide you will help. Have a nice Christmas and I hope to hear form you,

Best regards,
Beatriz Aguirre-Urreta

Appendix D

Appendix of Ar-Ar data

Table D.1: 40Ar/39Ar age determinations: Mesozoic Volcanics

Step	40Ar	39Ar	38Ar	37Ar	36Ar	40Ar*/39 Ark	39Ar cum. tot.	Age	±error (2 std. dev.)	Mean age	±error ($\sqrt{x^2+y^2}$)
(1) L5β (R22329 biotite)											
1	293.000	11.960	2.592	0.018	0.581	10.450	0.037	167.4	4.0		
2	581.700	30.420	7.818	0.026	1.011	9.500	0.130	152.7	2.8		
3	497.400	41.840	10.790	0.013	0.343	9.490	0.258	152.6	1.5		
4	755.800	35.500	9.301	0.015	1.632	7.994	0.367	129.4	3.5		
5	897.200	80.680	21.860	0.158	0.621	8.869	0.614	**143.0**	**1.5**	**143.5**	**2.1**
6	1270.00	113.500	30.160	0.131	0.878	8.926	0.962	**143.9**	**1.4**		
7	324.700	11.710	12.980	0.004	0.751	9.184	0.998	147.9	4.6		
8	46.840	0.489	0.084	0.006	0.151	6.571	1.000	107.0	18.0		
blank	0.400	0.110	0.114	0.118	0.125						
40/36air288.600											
(2) F9B (R22331 muscovite)											
1	3665.000	61.610	6.582	0.406	6.463	29.795	0.954	441.3	5.1		
2	8564.000	203.600	7.543	0.462	23.120	9.441	0.981	**151.8**	**6.2**	**151.8**	**6.2**
3	175.200	7.597	0.306	0.101	0.500	8.855	0.994	142.8	3.0		
4	297.700	3.510	0.245	0.158	1.038	9.909	0.999	158.9	15.0		
blank	0.400	0.108	0.114	0.118	0.125						
40/36air288.600											
(3) GA11C (R22333 biotite)											
1	110.500	1.842	0.260	0.112	0.440	12.223	0.005	194.2	30.0		
2	753.500	10.510	1.451	0.137	2.305	12.440	0.037	107.5	12.5		
3	1491.000	25.430	4.972	0.164	4.520	9.149	0.114	147.3	10.0		
4	319.700	16.640	4.273	0.130	0.695	9.487	0.165	152.5	4.2		
5	842.900	40.550	10.070	0.147	1.841	8.677	0.288	140.0	3.1		
6	1087.000	37.380	9.045	0.133	2.661	9.661	0.402	155.2	4.3		
7	1778.000	160.300	42.090	0.137	1.153	9.236	0.892	**148.7**	**1.0**	**150.3**	**1.8**
8	368.900	34.480	9.270	0.123	0.279	9.449	0.997	**151.9**	**1.5**		
9	34.030	1.120	0.370	0.118	0.202	12.778	1.000	202.5	45.0		
blank	0.400	0.108	0.114	0.116	0.112						
40/36air288.600											

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Table D.1: *continued*

Step	40Ar	39Ar	38Ar	37Ar	36Ar	40Ar*/39 Ark	39Ar cum. tot.	Age	±error (2 std. dev.)	Mean Age	±error ($\sqrt{x^2+y^2}$)
(4) CD9B (R22332 biotite)											
1	88.740	3.960	0.577	0.104	0.303	8.990	0.021	144.9	13.3		
2	3382.000	43.810	7.759	0.199	10.070	13.540	0.263	214.0	11.1		
3	800.200	19.840	3.139	0.160	2.454	7.270	0.372	118.1	7.6		
4	981.400	20.180	3.627	0.174	3.000	8.558	0.483	138.2	9.0		
5	1637.000	68.180	10.480	0.178	3.915	8.370	0.860	**135.2**	**3.2**	**138.1**	**4.9**
6	387.400	20.380	3.289	0.133	0.860	8.732	0.972	**140.9**	**3.7**		
7	75.100	4.955	0.913	0.161	0.231	8.521	0.999	137.6	10.0		
blank	0.400	0.108	0.114	0.116	0.112						
40/36air288.600											
(5) BERT2 (R22334 horneblende)											
1	2860.000	3.615	2.330	0.508	10.110	8.887	0.099	143.4	14.0		
2	2352.000	2.665	1.847	0.282	8.015	45.684	0.159	638.8	50.0		
3	1677.000	2.716	1.433	0.274	5.702	37.316	0.260	537.5	45.0		
4	634.600	12.770	10.830	5.358	2.047	7.235	0.570	117.5	3.5		
5	211.900	12.990	12.940	5.219	0.571	6.773	0.876	**110.2**	**8.4**	**107.7**	**12.2**
6	199.200	5.090	3.777	1.766	0.436	6.456	0.994	**105.2**	**8.8**		
blank	0.400	0.107	0.121	0.109	0.130						
40/36air283.400											
(6) Lago Esmeralda ESM1 (R22335 horneblende)											
1	220.500	1.013	0.525	0.193	0.883	16.490	0.027	257.4	45.0		
2	557.300	1.721	0.828	0.257	2.049	25.560	0.066	384.8	25.2		
3	130.900	1.514	0.468	0.228	0.556	9.142	0.191	147.2	29.0		
4	810.100	19.170	25.920	7.088	2.500	9.195	0.643	**148.0**	**2.0**	**148.3**	**4.0**
5	193.900	12.370	12.230	3.814	0.419	9.228	0.933	**148.5**	**3.5**		
6	47.860	1.800	1.163	0.411	0.222	11.246	0.973	179.4	24.0		
7	76.200	1.238	1.102	0.392	0.358	9.899	1.000	158.9	15.9		
blank	0.400	0.108	0.114	0.118	0.115						
40/36air266.500											
(7) PI62 (R22336 hornblende)											
1	113.100	0.979	0.298	0.154	0.545	0.077	0.030	1.3	40.7		
2	80.780	0.665	0.380	0.194	0.411	5.753	0.049	94.0	15.1		
3	1159.000	8.270	13.330	3.244	4.330	6.022	0.331	98.3	5.2		
4	367.900	16.380	29.690	6.828	1.133	6.026	0.893	**101.2**	**2.6**	**101.2**	**2.6**
5	43.540	0.578	1.034	0.309	0.272	5.731	1.000	93.7	14.0		
blank	0.400	0.116	0.114	0.118	0.125						
40/36air263.500											

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Table D.1: *continued*

Step	40Ar	39Ar	38Ar	37Ar	36Ar	40Ar*/39 Ark	39Ar cum. tot.	Age	±error (2 std. dev.)	Mean Age	±error ($\sqrt{x^2+y^2}$)
CF20 (R22330 biotite)											
1	13.130	0.129	0.134	0.111	0.167	1.321	0.043	22.0	30.0		
2	510.100	15.380	3.925	0.309	1.726	4.932	0.207	81.0	3.1		
3	929.400	37.250	7.674	0.400	2.780	5.603	0.604	**91.6**	**2.9**	**89.3**	**3.7**
4	501.000	37.070	7.677	0.295	1.244	5.314	1.000	**87.0**	**2.3**		
blank	0.100	0.116	0.114	0.118	0.125						
40/36air271.300											

K-Ar age data:		K wt.%	40Ar(rad) nl/g	Age Ma	
GA11C	22333bi	6.680	42.000	155	±2.8
LagoEsm.	22335hb	0.650	3.864	147.0	±3.4

Notes:

All mass peak measurements are in picoamperes.

Potassium decay constant = 5.543E-10 a-1

K-induced 40Ar/39Ar = 0.021

Ca-induced 39Ar/37Ar = 0.00078; 36Ar/37Ar = 0.000021

Calibration J value (based on standard biotite LP6, 127.9±1.2 Ma) = 0.0093

Errors for Age are two standard deviations.

Mean Age is an average of the boldface larger type Ages for each sample

Mean age error is a $\sqrt{x^2+y^2}$ combination of the boldfaced larger type Age errors for each sample

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Zane Bruce
Dept. of Geological Sciences
University of Canterbury
Private Bag 4800
CHRISTCHURCH

26 February 1999

Dear Zane
At last here are the Ar-Ar results of the Chilean, Jurassic-Cretaceous volcanic rocks you submitted last August. I had hoped to keep your work within a 4-6 month time-frame and it has been hard work to keep to this. In some ways, I have had to work very cautiously, because the equipent was to be (and has been) shut down on completion of your work, with no possibility of repeat analyses. In other ways, I have had to work fast and accept the sample and instrumental conditions as they arose - in most cases I would have preferred to do 'practice runs' to get the sensitivity a bit higher, and the heating schedule narrower at the lower temperature end (550-850°C) and wider at the high end (>1000°C). Also, the reactor people only irradiated the samples for 12 hours, instead of 72 (must have mis-read my 7 on the form, and they also persistently misunderstand our (sensible) day/month/year format for the US month/day/year one) and the amount of 39Ar in your hornblendes was 10 times too low. I also had a persistent high argon blank from the Cu foil packing envelopes (despite being 99.9% pure) - which reduced the precision of all the runs. The furnace argon blank was OK - I ran it 50 times over 2 months - but the Cu foil was uniformly 'gassy'. With more time I would have sent the samples back to the reactor for a full 72 hour blast and with some different Cu packing materials. I have analysed the results so that I can get some idea of this non-radiogenic, i.e 'air' argon in the samples; in most cases the 40Ar/36Ar ratio was normal, 286-288, but in one case, PI-62 it was extremely low and I find this hard to explain (but the age seems to have come out OK).

I also found it extremely hard to 'guess' the gas evolution over the 1000° temperature interval needed for all your samples - I did 9 steps, @100° each, from 550° to 1450° (this is the usual accepted scheme) - but in most cases the gas came off 'too fast' at the low temperatures and was exhausted by the later steps. It is hard to judge these things so that the gas extracted (a) is enough for an analysis, but (b) not too much and too rapidly evolved to prevent seeing a good thermal-age spectrum. In most cases I only achieved 5-7 steps - which disappointed me - and I have decided to charge you on a 'step-achieved' basis, rather than a full, 10-step basis. A full 10-step analysis would be $1500 (@$150 per step) discounted, as agreed in your case, to $1000 (@ $100 per step). I also had a 'bad-hair day' with sample FP9, for which I accidentally pumped away steps 2-3 - this sample was odd in that a very high proportion of the argon was released at <550°C) - the remaining data for this do not look too bad - but again I have decided not to charge you for this cock-up.

The good news. All the samples give nice late Jurassic or mid-Cretaceous ages. They are calibrated against the well-known American LP6 biotite standard (127 Ma), ideal for your work. The data also show, as one might expect, that the hornblende samples do have significant amounts of excess 40Ar (i.e. not produced by in situ decay of 40K). Also, in retrospect, I think sample PI62 has too low a K content (about 0.35%) for a reliable age - at this level, excess argon becomes a common and difficult factor in the age interpretation. In each case it is thus prudent to make a sensible, if subjective estimate of the age by avoiding the excess argon steps, and averaging the ages for the best remaining parts of the age plateau, usually in the range of steps 4-6. This behaviour is quite normal - and personally, I don't like doing age interpretations on these 'saddle-shaped' age spectra - I am far happier with biotites and muscovites for which you can average a few more central steps in a plateau region where the age precision looks good. But I will leave the final judgement, albeit a bit subjective, to you.

I hope it all makes sense,
Regards,

Chris.

Chris Adams.

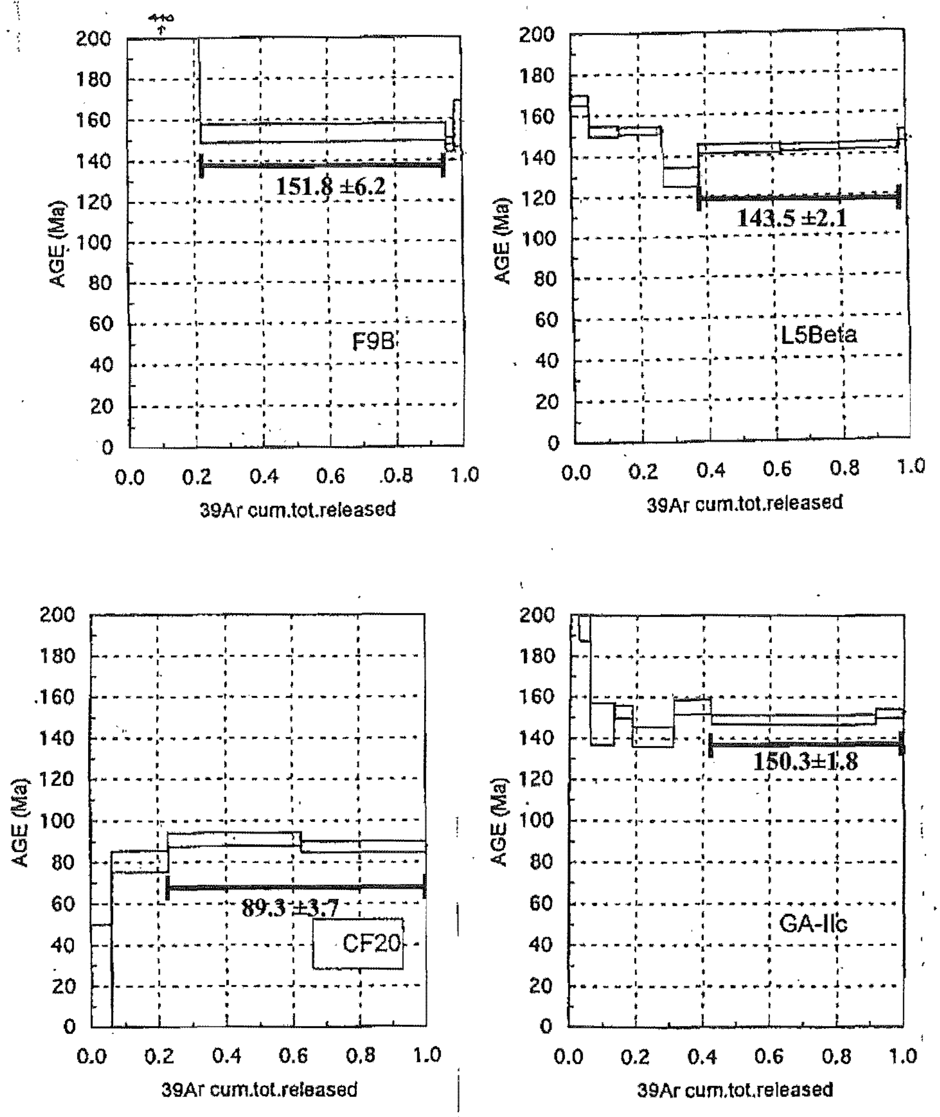

Figure D.1: 40Ar/39Ar age determination: Mesozoic Volcanics: Gas release Spectra 1.

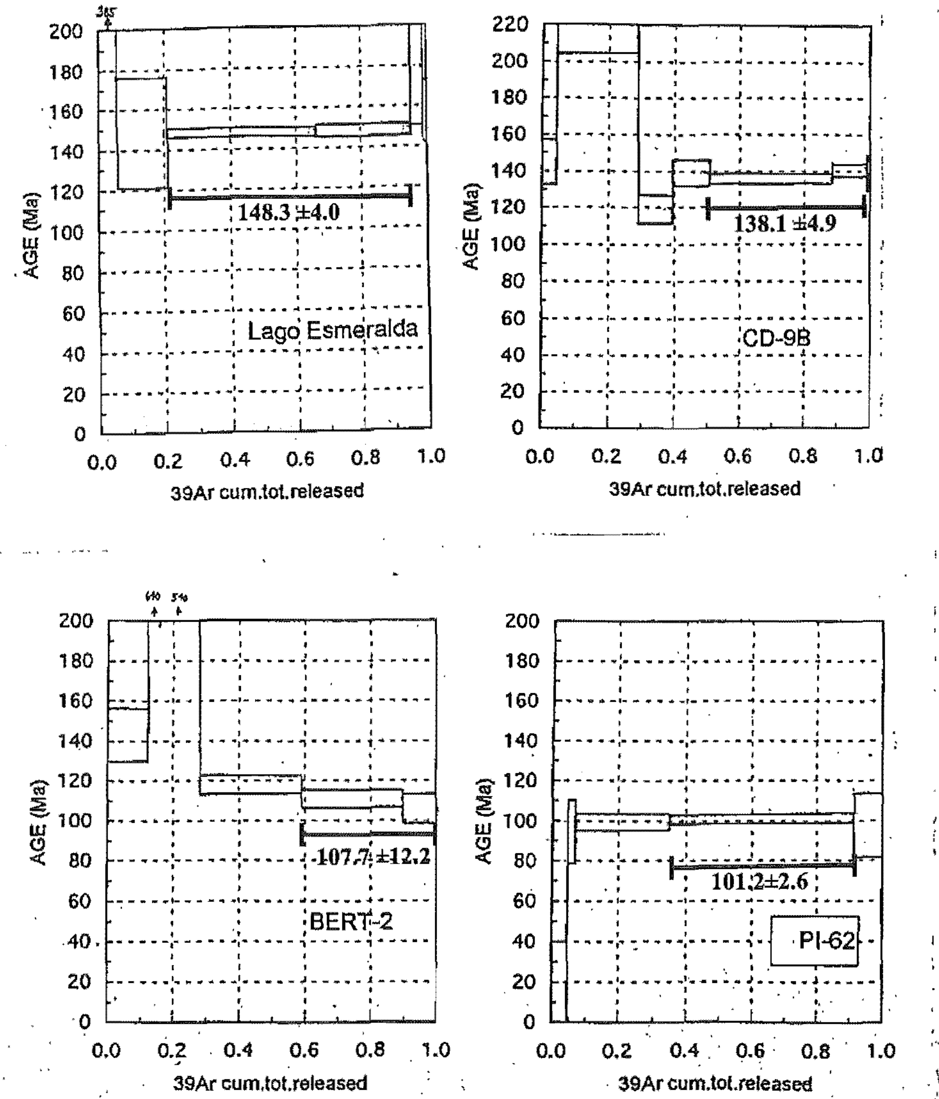

Figure D.2: 40Ar/39Ar age determination: Mesozoic Volcanics: Gas Release Spectra 2.

Appendix E

Publications

E.1 Paper presented at the 1997 Congreso Geológico Chileno:

E.1.1 Recent Work on the Stratigraphy of Mesozoic Rocks in the Aysén Region, 44-47^o S: In Particular the Upper Jurassic Ibáñez Formation

Zane R. V. Bruce [1]
Supervisors:
S.D. Weaver[1], J.D. Bradshaw[1], and Manuel Suárez[2]

[1] Department of Geological Sciences, University of Canterbury, Private Bag 4800, Christchurch, New Zealand.
[2] Servicio Nacional De Geologia Y Mineria; Avinida Sante Marie, 0104, Santiago, Chile.

E.1.2 Introduction

The Eastern Aysén Region from 45^o-47^{o}S is characterised by Jurassic and Cretaceous silicic volcanic rocks and volcaniclastic terrestrial rocks, comprising two major formations separated by shallow marine and continental sediments. In the Puerto Ingeniero Ibáñez region, these rocks have been mapped at 1:50000 scale to discover new information on their stratigraphic relationships. Of the two volcanic Formations, the Late Jurassic Ibáñez Formation is dominated by thick tuffs and ignimbrites, and is more deformed, while the Lower Cretaceous Divisadero Formation is characterised by tuffs and tuffaceous floodplain sediments. The division between these two volcanic Formations is the Coyhaique Group, of Lower Cretaceous marine black shales and tidal sandstones. This sequence is cut by both hypabyssal volcanic rocks and outlying stocks of granitic rocks associated with the Patagonian Batholith.

E.1.3 Geological Setting

Mid and Upper Jurassic silicic volcanic rocks, locally named the Ibáñez Formation [1], [2] overlie Palaeozoic semi-pelitic schists. Within the area mapped in the summer 1995-96, the Palaeozoic schist basement does not occur as outcrop, but is common as lithic fragments in some of the ignimbrites, and as large xenoliths in one of the minor intrusive bodies. The Ibáñez Formation is at least 1000 m thick, and consists of a faulted sequence of rhyolitic and dacitic domes, tuffs and ignimbrites, with some andesitic lavas and pyroclastic rocks, intercalated with continental lacustrine and fluvial sediments and minor marine incursions in the upper part of the unit [3]. This Formation has been variously ascribed to subduction related volcanism [4], [5] or grouped with the large Chon-Aike/Marifil/Tobifera silicic province, suggested to be due to large scale crustal anatexis during the rifting precursor phase of Gondwana separation [6], [7].

Unconformably overlying the Jurassic igneous rocks is a transgressive-regressive sequence, the Lower Cretaceous Coyhaique Group of shallow marine rocks forming the northern expression of the Austral Basin [8]. This Group consists of discontinuous limestones, tuffs and fossiliferous sandstones (Toqui Formation), overlain conformably by a thick (up to 600m,) extensive unit of fossiliferous black shales (Katterfeld Formation), which in turn grades abruptly into the Apeleg Formation, a homogenous unit of ripple and trough crossbedded sub-tida (and locally deltaic) shallow marine sandstones [9], [10].

Overlying the Coyhaique Group are the volcaniclastic rocks of the Divisadero Formation, a Lower Cretaceous silicic volcanic unit with flood-plain deposits and some deltaic facies, together with widespread tuffs, ignimbrites, and remnant rhyolitic, dacitic and andesitic eruptive centres [2]. Above the Divisadero Formation are patches of Late Cretaceous and Tertiary flood basalts, including some possible eruptive centres.

The entire sequence is cut by several generations of intrusives, both the Mid-Cretaceous to Miocene granitoids of the main Patagonian Batholith to the west, and numerous local hypabyssal intrusives and dikes ranging from the Jurassic through to Tertiary and Recent. Active volcanism in the region is represented by Volcan Hudson, and there is also evidence of basaltic pyroclastic rocks and subglacial pillow lavas during the last glaciation [11].

E.1.4 Jurassic Stratigraphy

Within the area studied, the Ibáñez Formation is dominated by silicic volcanic rocks, mainly tuffs and ignimbrites. Extrusive lavas are less common, but areas of dacitic to rhyolitic lavas and domes occur, as do minor andesitic lavas and pyroclastic rocks. Cutting the Formation are large numbers of minor normal and some reverse faults, which make correlation of individual units difficult. In the Rio Ibáñez valley itself, many of these faults show a strong south-east to north-west alignment, and slickensides indicate both vertical and sub-horizontal movements. Ignimbrites in this area are generally five to twenty metres thick, although some show ponding up to 100 metres. Most are massive units, with simple cooling features, and columnar jointing is rare. From the lack of columnar jointing and the poor preservation of microscopic shard textures, it is difficult to distinguish primary welding from diagenetic features. In the lower parts of the exposed sequence, an ignimbrite with unaltered biotite has yielded a K-Ar age of 150 million years [12]. Intercalated with the tuffs and ignimbrites are sedimentary units, including fluvial deposits, mass flow deposits and laminated pelites. These sediments are occasionally fossiliferous, but contain only wood fragments, leaves and trace fossils, and as yet no body fossils have been found. In several places around Puerto Ibáñez, large ignimbrite units are absent, and the formation consists of silicic lavas, breccias, tuffs and other volcaniclastic units, some of which are block and ash deposits directly associated with remnant dacitic and rhyolitic domes. Towards the upper part of the sequence, and locally just below the contact with the Coyhaique Group, Ibáñez Formation tuffs and thin ignimbrites are weathered to a distinctive purple clay, and are associated with remnant fluvial gravels. Associated with this apparent palaeotopography are isolated occurrences of aa andesitic lavas and some pyroclastics, infilling valleys eroded into older silicic Ibáñez rocks.

E.1.5 Upper Jurassic-Lower Cretaceous Stratigraphy

The base of the Coyhaique Group to the north-east of Puerto Ibáñez is poorly exposed, and in places disrupted by later Cretaceous and perhaps Tertiary intrusives. Between Cerro

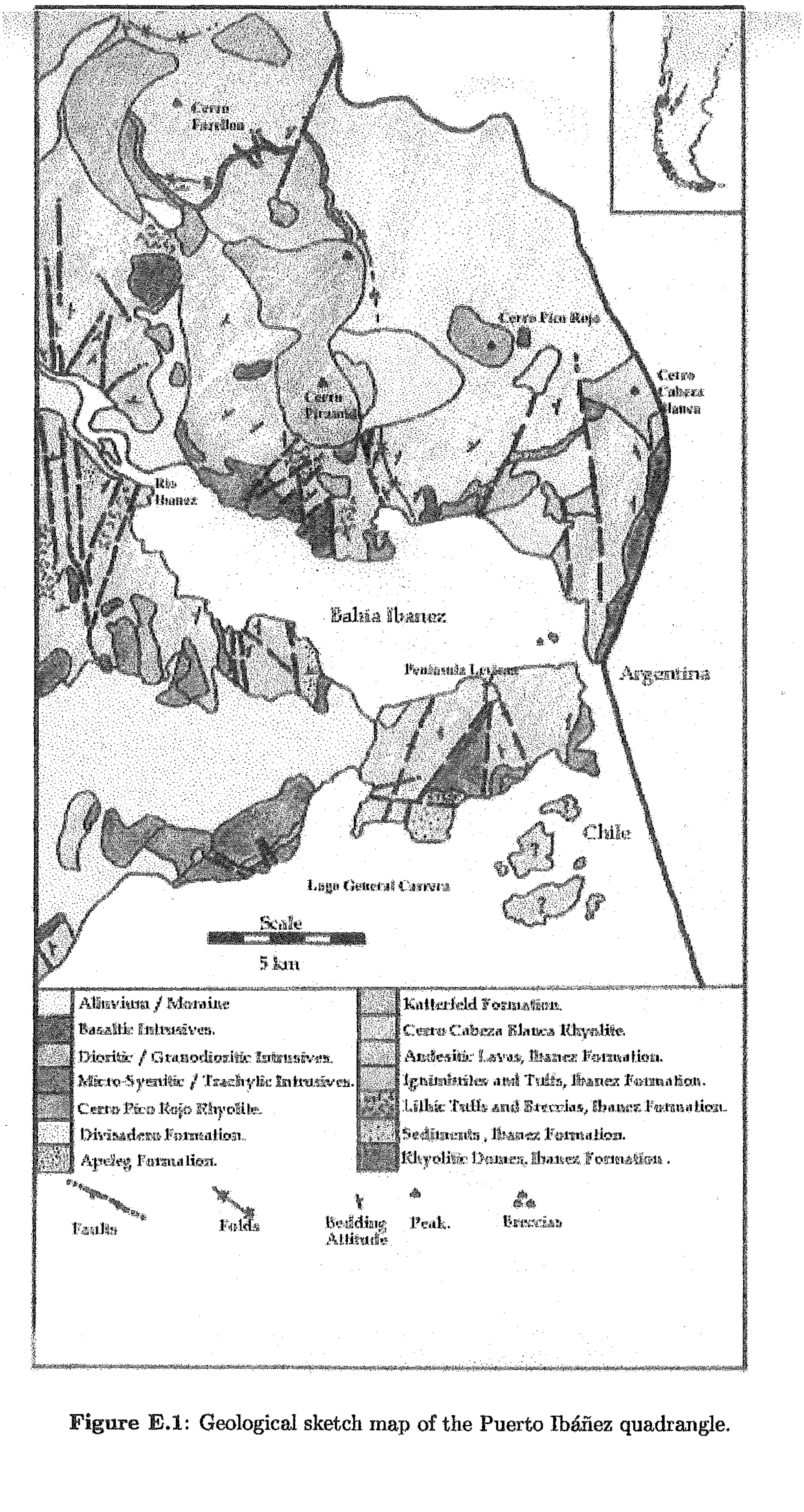

Figure E.1: Geological sketch map of the Puerto Ibáñez quadrangle.

Pirámide and Cerro Farellón, the first indications of the Coyhaique Group are outcrops of black shales of the Katterfeld Formation. The base is not well exposed, and the shale has been disrupted by several different intrusions. Black shales outcrop over a large area between the two mountains, and are perhaps up to five hundred metres thick. However, further to the east at Cerro Cabeza Blanca, near the border with Argentina, the Katterfeld Formation is very thin or not present, and the overlying Apeleg Formation displays onlap relationships to the weathered paleotopography of the Ibáñez Formation. Locally, the Katterfeld Formation is responsible for landsliding that repeats some stratigraphy of the Apeleg Formation. The shales are fossiliferous in places, with ?Crioceratites Ammonoid species, Ostrea fragments, Bivalves, bone fragments and shark teeth. At its upper contact the Katterfeld Formation grades abruptly into thickly bedded Apeleg Formation.

The Apeleg Formation to the north-east of Cerro Pirámide displays foreset cross-bedding, fining upward sequences, and grades upwards into continental redbeds of the Divisadero Formation, with channels and algal limestone fragments. The sandstones are 100 to 120 metres thick, with individual beds up to three metres thick, dominated by coarse and very coarse sands and fine gravels but varying to rippled fine sands and some shales. The upper part of the underlying Katterfeld Formation rapidly coarsens upward from carbonaceous mudstones, shales and siltstones, through fine sandstones to Apeleg Formation thickly bedded coarse sands, which then display two fining upward sequences, the upper of which grades into the overlying Lower Divisadero Formation redbeds. The upper parts of the Apeleg Formation and lower parts of the Divisadero Formation redbeds have both carbonised and petrified tree trunks, but not in life position.

The Divisadero Formation crops out in the north-east of the area mapped, and is dominated by tuffs and tuffaceous sandstones. It is preceded by the deltaic transition from Apeleg Formation to Divisadero Formation continental redbeds. The redbeds in places grade into the overlying tuffs and ignimbrites of the Divisadero Formation proper, but in at least one location the contact with the Divisadero is paraconformable, (truncated dike at Cerro Cabeza Blanca.) Ignimbrites are less common than in the Ibáñez Formation, and generally less altered. Some still display deformed glass shard textures, but there are fewer welded, columnar, or complexly stratified ignimbrites. A significant feature of this Formation are the common, well preserved accretionary lapilli that occur in the tuffs. Channel structures and conglomerates occur, notably in the redbeds at the base of the formation, but can also occur at higher levels. As with the Coyhaique Group, between Cerro Farellón and Cerro Pirámide, the Divisadero Formation is locally deformed and cut by later intrusive rocks. There are significantly fewer faults displacing the Cretaceous rocks, as compared with the densely faulted Ibáñez Formation. However, what faults do occur have significant displacements. West of Cerro Pirámide, Rocks of the Ibáñez Formation are reverse faulted over the Divisadero Formation by a minimum of five hundred metres, whereas within the Divisadero, discrete normal and reverse faults occur, but without the dense faulting of the Jurassic rocks. Although dominated by tuffs and tuffaceous sediments in this area, in the upper exposure of the Divisadero Formation at Cerro Pico Rojo there is a remnant peralkaline rhyolite dome which retains parts of coulee flows and small pumice flows.

E.1.6 Intrusive Rocks

Intrusive rocks occur throughout the sequence, and in many cases are the least altered rocks available for analysis. There are two groups, microgranitoids and hypabyssal intrusives. The microgranitoids are of dioritic to granodioritic compositions and outcrop as irregular stocks and arcuate bodies. Some maintain granitic textures, but others grade into fine grained hypabyssal rocks. All have had moderate thermal metamorphic effects on the country rock, with contact aureoles ranging from a few tens of metres to perhaps a hundred metres wide. Small epithermal Pb/Zn/Cu-quartz veins and mineralised breccias occur within the contact aureoles of these rocks. The hypabyssal rocks are dikes, sills and irregular stocks, of compositions ranging through basaltic to rhyolitic, and including some trachytic rocks. Some sills are able to be traced up to three kilometres. The densely faulted Ibáñez Formation is host to the majority of dikes, some of which are coeval with Jurassic activity, but many of which post-date it. Breccia pipes are also present. These minor intrusive rocks are difficult to separate into distinct age groups, and represent the combined subvolcanic intrusives from the Jurassic to Tertiary. Many of the dikes within the Ibáñez Formation are cut by the faults confined to the Ibáñez Formation, and can be tentatively assigned to the Late Jurassic. This includes dikes, sills and stocks of andesitic, trachytic and rhyolitic compositions, ranging from dikes and sills a metre thick to bodies up to several hundred metres across. Several of the intermediate sized intrusions up to a kilometre across, of trachytic and basaltic compositions, cut all rocks up to the Divisadero Formation, and so can be assigned ages of Mid Cretaceous or younger. The larger granodioritic intrusions also cut the sequence up to and including the Divisadero Formation, and can also be assigned to the Mid Cretaceous or Tertiary.

E.1.7 Discussion and Conclusions

As both fieldwork and analysis are still in progress, any regional synthesis is premature. However, the following tentative conclusions can be put forward:

1) The Ibáñez Formation has physical characteristics consistent with a large rhyolitic province, with an area of approximately 14,000 square kilometres. Ignimbrite outflow sheets and tuffs are intercalated with fluvial and possibly lacustrine sediments, and occasionally with dacitic and rhyolitic domes, breccias and associated pyroclastic rocks. Andesitic rocks occur more towards the upper part of the sequence. Faulting of the sequence makes exact stratigraphic correlation difficult.

2) The upper parts of the Ibáñez Formation show significant weathering and paleotopography varying as much as 600 metres, as can be estimated from the changes in thickness of the overlying Katterfeld Formation of the Coyhaique Group, and the onlap relationships the Coyhaique group rocks display towards the upper Ibáñez paleotopography.

3) The occurrences of the Coyhaique Group and Divisadero formation are consistent with the marine transgressive-regressive sequence and prograding volcaniclastic deltaic interpretations given to them by previous workers.

4) Although both the Ibáñez and Divisadero Formations in this locality are deformed, the Ibáñez Formation shows a much greater density of faults than the overlying rocks.

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E.1.9 References

1) Skarmeta, J. 1978. Geologia de la Region Continental de Aysén entre el Lago General Carrera y la Cordillera Castillo, Carta Geologica de Chile No 29. Escala 1:250,000. pp 53

2) Niemeyer, H., Skarmeta, J., Fuenzalida, R., Espinosa, W. 1984. Hojas Peninsula de Taitao y Puerto Aysén , escala 1:500,000, Region de Aysén del General Carlos Ibáñez del Campo. Carta Geologica de Chile No 60-61 , Servicio Nacional De Geologia Y Mineria, Santiago, Chile. 80 pp

3) Covacevich, V., De la Cruz, R., Suárez, M. 1994. Primer Hallazgo de fauna del Berriasiano Inferior (Neocomiano) en la Formacion Ibáñez, Region XI, Aysén. Actas Septimo Congresso Geológico Chileno, Concepcion.

4) Demant, A. 1995. Volcanic Stratigraphy of the Northern Patagonian Andes, Coyhaique Region (44 - 46° S), Chile. In: Abstracts, Andean Geosciences Workshop. Kingston University.

5) Gust, D. A., Biddle, K.T., Phelps, D.W., Uliana, M.A. 1985. Associated Middle to Late Jurassic volcanism and extension in southern South America. Tectonophysics, 116, pp 223-253.

6) Bruhn, R.L., Stern, C.R., Dewit, M.J. 1978. Field and geochemical data bearing on the development of a Mesozoic volcano-tectonic rift zone and back arc basin in southernmost South America. Earth and Planetary Science Letters, 41, pp32-46.

7) Pankhurst, R.J., and Rapela, C.R., 1995. Production of Jurassic rhyolite by anatexis of the lower crust of Patagonia. Earth and Planetary Science Letters, 134, pp 23-36.

8) Riccardi, A.C. 1988. The Cretaceous System of Southern South America. Memoir / Geological Society of America. 161 pp.

9) Bell, C.M., Townsend, M.J., Suárez, M., and De la Cruz, R. 1994. The depositional environments of the Lower Cretaceous Coyhaique Group, Aysén Basin, southern Chile (45-46° S). Actas Septimo Congreso Geológico Chileno, Concepcion.

10) Suárez, M., and De la Cruz, R. 1993. Mesozoic Stratigraphy and Palaeogeography of northern Patagonian Cordillera, (Lat 45- 47° S), Chile. Abstracts, Second ISAG, Oxford UK. pp21-23.

11) Belmar, pers. comm. 1995

12) Suárez, M., and De la Cruz, R. 1997. Edades K-Ar del Grupo Ibáñez en la parte oriental del Lago General Carrera (46°-47° S) Aysén, Chile. VIII Congreso Geologico Chileno. pp 1548-1551.